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CHARLES F. MARVIN, Chief

MONTHLY WEATHER REVIEW

VOLUME 47, No. 6

JUNE, 1919

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INTRODUCTION.

The MONTHLY WEATHER REVIEW contains (1) meteorological and seismological contributions and bibliography; (2) an interpretative summary and charts of the weather of the month in the United States and adjacent oceans; and (3) climatological and seismological tables dealing with the weather and earthquakes of the month.

The contributions are principally as follows: (*a*) results of the observational or research work in meteorology carried on in the United States or other parts of the world, in the Weather Bureau, at universities, at research institutes, or by individuals; and (*b*) abstracts or reviews of important meteorological papers and books. In each issue of the REVIEW such contributions and abstracts are grouped by subjects, roughly, in the following order: General works, observations and reductions, physical properties of the atmosphere, temperature, pressure, wind, moisture, weather, applications of meteorology, climatology, and seismology.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but the publication of such contributions is not to be construed as official approval of the views expressed.

The partly annotated bibliography of current publications is prepared in the Weather Bureau Library. Persons or institutions receiving Weather Bureau publications free should send in exchange a copy of anything they may publish bearing upon meteorology, addressed "Library U. S. Weather Bureau, Washington, D. C.," in order that the monthly list of current works on meteorology and seismology may be as complete as possible. Similar contributions from others will be welcome. Bibliographies of selected subjects are published from time to time in the REVIEW.

The section on the weather of the month contains (1) an interpretative discussion of the weather of North America and adjacent oceans, and some notes on the weather in other parts of the world; (2) details of the weather of the month in the United States; and (3) brief discussions of weather warnings, rivers and floods, and weather and crops. There are illustrative charts. The climatological tables comprise summaries of the weather and excessive precipitation data for about 210 stations in the United States, and summaries of the weather observed at about 30 Canadian stations.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are due especially to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The seismological tables contain, in a form internationally agreed on, the earthquakes recorded on seismographs in North and Central America. Dispatches on earthquakes felt in all parts of the world are published also.

Since it is important to have as the name of the month appearing on the cover of the REVIEW that of the period covered by the weather discussions and tables rather than that of the month of issue, the REVIEW for a given month does not appear until about the end of the second month following.

Supplements containing kite observations and others containing monographs are published from time to time.

SOME WEATHER BUREAU PUBLICATIONS.

A few of the more recent Weather Bureau publications are listed below, with their prices. A complete list may be obtained upon application to the *Chief, U. S. Weather Bureau.*

To secure such publications as have a price affixed, one should apply to and make remittances payable to the *Superintendent of Documents, Government Printing Office, Washington, D. C.* Stamps and personal checks are not accepted in payment. Additional charge for postage for foreign addresses.

National Weather and Crop Bulletin, with charts, monthly from October to March, weekly during remainder of the year	25c. a year.
Snow and Ice Bulletin, with charts, weekly during the winter	25c. season.
Climatological data, monthly for 42 separate sections, each section 5c. a copy	50c. a year.
Complete monthly number, 42 sections	35c. each, $4.00 year.
Monthly Weather Review Supplement No. 9. (Periodical events and natural law as guides to agricultural research and practice)	25c.
Monthly Weather Review Supplements Nos. 10 and 11. (Aerology Nos. 5 and 6), 1917 kite data	25c. each.
Monthly Weather Review Supplements Nos. 12 and 13. (Aerology Nos. 7 and 8), 1918 kite data, etc	25c. each.
Weather forecasting in the United States	$1.25
The daily weather map, with explanation (text and 4 charts)	5c.
Instructions for cooperative observers, 6th ed. Circulars B and C combined	10c.
Instructions for the installation and operation of Class A evaporation stations. Circular L	10c.
Papers on meteorology as a subject for study. (Repr. from Dec., 1918, Mo. Wea. Rev.)	Free.
Report of the Chief of the Weather Bureau, 1917–1918 (4° edition)	Free.
Modern methods of protection against lightning. (Farmers' Bull. No. 842)	Free.
Notes on the climate of France and Belgium	Free.
The Weather Bureau. (Descriptive pamphlet)	Free.
Explanation of the weather map (leaflet)	Free.
Serial numbers of Weather Bureau publications	Free.
General classification of meteorological literature (leaflet). (Repr. from Jan. 1919, Mo. Wea. Rev.)	Free.

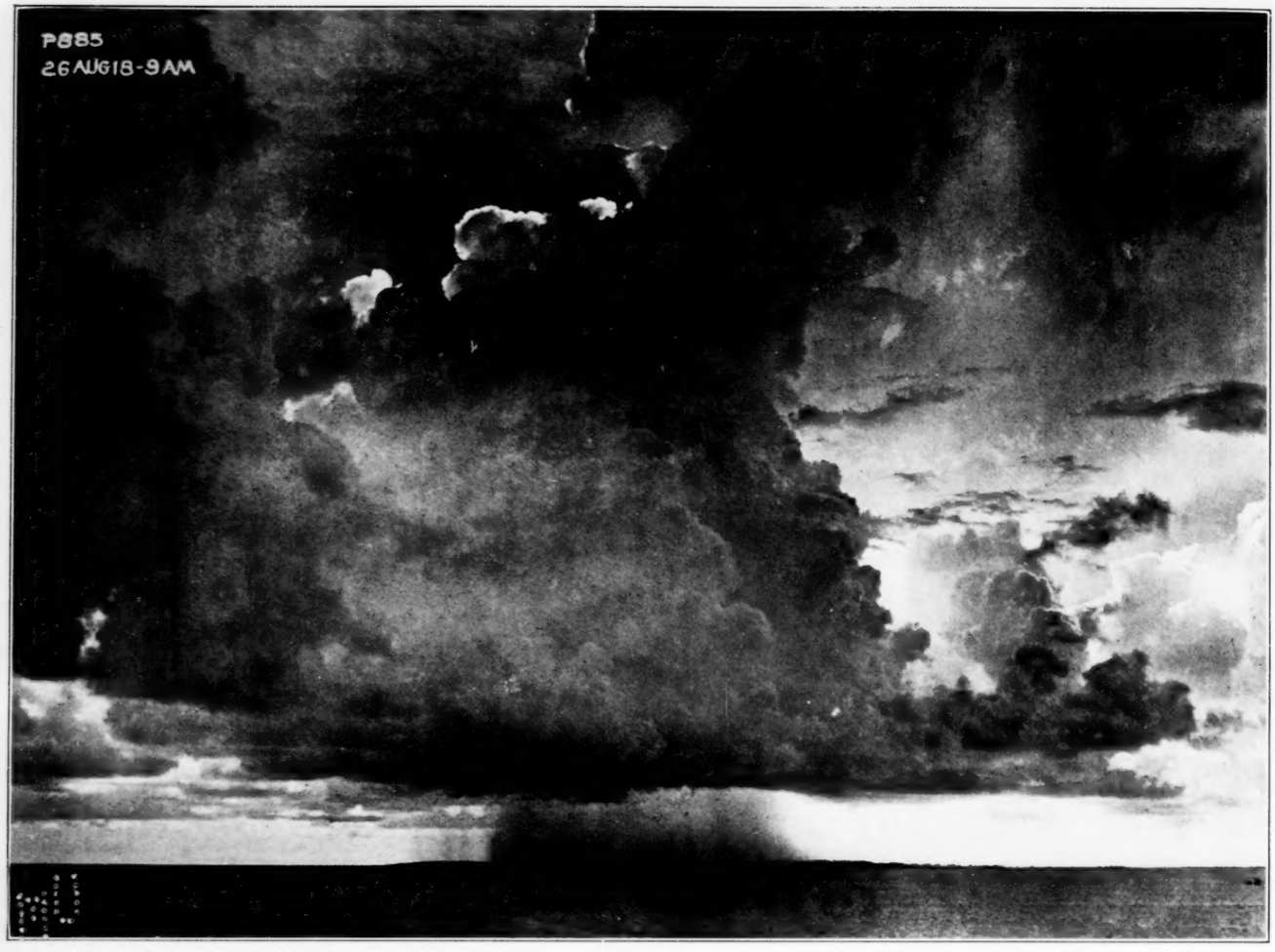
As the surplus of MONTHLY WEATHER REVIEW, February and April, 1919, is limited, recipients who do not care to retain their copies will confer a favor by notifying the Chief of Bureau, who will arrange for the return postage.

CORRIGENDA.

REVIEW, January, 1919:

Page 29, second column, third line above the diagram, *for* "one-hundredths" *read* "one-hundredth."

Page 30, Table 2, Rio Grande, 1913, second column, *for* "5.544" *read* "5.844". Same table, Brazos Brook, 1909, fourth column, *for* "5.566" *read* "5.366". Same table, Gatun Lake, 1911, twelfth column, *for* "3.376" *read* "5.376."



Thunderstorm due east of Pensacola, Fla., 9 a. m. (90th mer. "summer time"), Aug. 26, 1918. Photographed by Lieut. W. F. Reed, jr., U. S. N. R. F. (Published by permission of the Navy Department.)

Observations at 9 a. m.: Showers due east and due west of station moving northward; lightning and thunder; barometer 30.06 in.; temperature, dry bulb 85.0, wet bulb 78.0; wind SE., 8-9 mi/hr.; clouds, .3 Ci. and .2 Ci.St. from NW., .1 Cu., .3 Cu.Nb. and .1 St. from S.

MONTHLY WEATHER REVIEW

CHARLES F. BROOKS, Editor.

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W. B. No. 688.

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ISSUED SEPTEMBER 13, 1919

CONTRIBUTIONS AND BIBLIOGRAPHY.

SOME OBSERVATIONS ON TEMPERATURES AND WINDS AT MODERATE ELEVATIONS ABOVE THE GROUND.

By VINCENT E. JAKL, Meteorologist.

[Dated: Aerological station, Drexel, Nebr., May 16, 1919.]

SYNOPSIS.—This article is based on the free-air observations by means of Marvin-Hargraves kites begun at Drexel, Nebr., in October, 1915.

Average annual temperature gradients in the lower air over any region are dependent largely on the intensity and persistence of the winter temperature inversions, for in summer surface heating produces local convection which results in nearly uniform vertical temperature gradients over wide areas. The gradient at any time is dependent largely on wind direction at different levels, especially in winter.

The winter vertical temperature gradients over Drexel are the result of the successive cold and warm-wave conditions. In the cold wave the cold air arrives first near the surface and gradually affects higher levels. Near the ground turbulence and heating by day may maintain a thin sheet in which there is a lapse in temperature, but the general condition is one of inversion. Near the center of the anticyclone dynamic warming by the compression of the descending air is sometimes in evidence aloft. Then a shift of wind to south will raise the temperature at some distance above the surface several hours before the slower-moving surface wind arrives.

The degree of diurnal change of surface wind depends on the vertical temperature gradient as well as on the relative velocities of the upper and lower winds, convectional interchange being greater when the gradients are steepest.

Gradient winds computed from sea-level isobaric charts frequently do not agree at all closely with those observed a few hundred meters above the surface at Drexel (itself at 396 m.), for, aside from arbitrary assumptions in sea-level reductions, the diverse temperatures of the air over neighboring regions may make the slopes of the isobaric surfaces even at moderate heights differ considerably from those indicated by the sea-level charts.—*C. F. B.*

INTRODUCTION.

A large portion of the readers of the REVIEW other than those actively engaged in upper-air work find it hard to interest themselves in the mere tabulated record of upper-air observations. As the period of observations at any aerological station becomes longer, I believe a more descriptive treatment can be given the published results. This, in my opinion, should encourage a more general study and discussion of upper-air data among those who have heretofore looked upon these records as something rather foreign to their own work and lines of thought.

THE "LAPSE-RATE" OF TEMPERATURE.

In a table of average annual free-air temperatures over practically any station a continuous "lapse" in temperature with elevation from the ground to the isothermal layer, or stratosphere, is shown. This word "lapse" is taken from the English publications as more appropriate than the awkward alternative, "positive vertical temperature gradient." The expression "inverted rate" is used to convey the opposite meaning. The lapse rate varies somewhat for different places, according to their latitude, altitude, and exposure, but it is probable that the tendency of this rate for successive large intervals of elevation, as shown by data already available, is universal.

GENERAL CONDITIONS AFFECTING GRADIENTS.

A discussion of the processes arising out of insolation, radiation, and convection that establish and maintain these vertical temperature gradients would only be a repetition of an already exhaustive treatment of the subject. By way of introduction to the subject of this paper, which it is intended to confine to observations on temperatures and winds at moderate elevations, it need only be pointed out that the lapse rate on the average increases from the ground to nearly the isothermal layer; that from about 4,000 meters altitude to about 9,000 meters it approaches the adiabatic rate for dry air, and is rather uniform with altitude, season, and place; and that below about 4,000 meters the lapse rate averages approximately half the adiabatic rate for dry air, but with marked differences between the seasonal means.

Winter vs. summer gradients.—The limitations imposed on the lapse rate by convection and the liberation of latent heat of condensation of the moisture content of the air operate to maintain a comparatively uniform rate over different inland places in summer; while in winter a lower lapse rate (or greater inverted rate) can be inferred for higher latitudes and longer continental exposure. It will therefore be found that the variation in the average annual vertical temperature gradients below about 4,000 meters, for different inland places, is largely determined by the different winter values of these rates.

Wind and temperatures aloft.—The influence of wind direction and force on vertical temperature gradients is apparent when comparing daily free-air gradients with the normal gradients for the season. Seasonal averages are simulated frequently on summer days, but more rarely in winter, the deviations from the normal winter curve increasing in frequency and amount as lower altitudes are considered. This is a result of the steeper horizontal temperature gradients, the greater wind force, and more abrupt changes in wind direction prevalent in winter. A consideration of the free-air records of Drexel, Nebr., as bearing on the relation of winds and temperatures at altitudes well below 4,000 meters, or within the usual range of kite flights, may be of interest, from the fact that the central location of this station is representative of considerable of the interior portion of the country and affords data in this respect heretofore not available for a typical continental exposure.

WINTER VERTICAL TEMPERATURE GRADIENTS OVER DREXEL.

Table 1 gives seasonal free-air temperatures and gradients for Drexel, determined from about two and a half years' record. A change that will to some extent affect the values of the gradients may be expected from additional years of observations, but the tendency or direction of the curve indicated by the gradients will undoubtedly remain the same. These figures are, moreover, frequently given partial verification by observations on days that seem typical of their respective seasons.

The winter temperature gradients at Drexel well illustrate its continental exposure. To verify further the figures in Table 1 for the colder portion of the year, an effort has been made to compute 24-hour mean gradients for altitudes extending to 2,000 meters above sea level, or about 1,600 meters above station, above which the diurnal change is usually not large. The result, shown in Table 2, was determined from the records of such continuous 24-hour free-air observations as were occasionally possible during a period of nearly four years, and therefore represents averages based on observations varying in number for the different months.

Table 2 qualifies the corresponding data in Table 1 only as typifying a more stagnant state of the atmosphere, inasmuch as Table 1 is the mean of all available observations, while the observations included in Table 2 were mostly taken in clear weather. Table 2 should furthermore be accepted with the reservation that it is based on decidedly fewer observations than Table 1. Further reference to these tables will be made in the following paragraphs.

As, on the average, the winter radiation, during a 24-hour period, is far in excess of the concurrent insolation, and as this excess is not easily offset by warm winds, owing to remoteness from large bodies of water, the tendency is for an accumulation of cold air over an extended area. This cold layer is stagnant as regards ability of the warmer winds above to intermix with it, and consequently builds up until a well-defined storm or low pressure area dispels it. Table 1 illustrates the comparative permanence of this cold layer above the ground in winter, and Table 2 its progressive deepening with advance of the season. It is conceivable that the cold waves that at intervals visit a considerable portion of the country throughout the winter, owe their inception to just such processes in the regions to the north and northwest, whereby extensive, rather deep masses of cold air build up, consequent upon a prolonged undisturbed radiation.[1]

A number of instances of this persistence of low temperatures in the layers near the ground may be found in the published records of free-air observations taken continuously for 24 hours or more. A good type of winter vertical temperature gradients during a period when normal surface temperatures prevailed, is afforded by the diurnal series record of February 14–15, 1916, (**2**). It will be noted that an inversion at an average altitude of about 1,400 meters above sea level, or 1,000 meters above the ground, was continuous throughout the 33 hours of the series, and that insolation during the day was effective in restoring the normal lapse rate in a layer extending only a few hundred meters above the ground. Above the inversion layer, and extending to about 3,100 meters from the ground, a lapse rate was maintained, and the temperature showed only slight diurnal variation till about the last 12 hours of the series, when a sustained rise in temperature, preceding and attending a steady fall in pressure, set in. The rise in temperature in the higher layers was not uniform with altitude, as is apparent in the small scattered inversions at various heights.

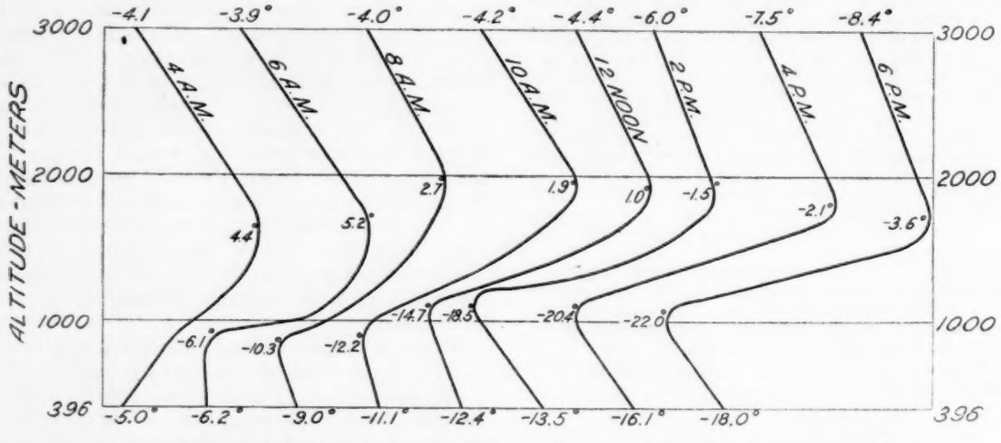

FIG. 1.—Progressive temperature gradients in cold wave of Dec. 27, 1917, at Drexel. Temperatures in °C.

The afternoon rise in temperature in the layers immediately above the ground, plays a part in establishing the small average winter lapse rate in the very lowest layers, as shown in Table 1, and suggested in the midwinter month in Table 2. While the observations entering into Table 1 were made principally in the daytime, this reversal of the inverted rate near the ground in winter is not necessarily confined to the daylight hours. Due to the prevalence at this time of year of winds that are cold at their base, but which, on account of the retardation and vertical currents induced by surface friction, show lowest temperatures at that small altitude above the ground where surface friction is for the most part surmounted, a lapse rate may be evident the first two or three hundred meters above the ground, irrespective of the time of day. Low-lying clouds, prevalent in winter, also play an important part in establishing a lapse rate from the ground to their base.

Progressive vertical temperature gradients in a cold wave.—Figure 1, adapted from the chart accompanying

[1] Cf. MONTHLY WEATHER REVIEW SUPPLEMENT No. 12 (Aerology No. 7, pp. 9-12; and MONTHLY WEATHER REVIEW, **46**, No. 12, pp. 570-580.—W. R. G.

the record of the diurnal series of observations taken on December 26–27, 1917 (3), shows successive vertical temperature gradients at two-hour intervals during the advance of a cold wave. This graphic method, differing from the chart from which it is adapted, in that the temperature lines are isochronous instead of isothermal, has been chosen as possibly representing a vertical plane in the line of advance of a cold wave. (The same method has been used in graphically illustrating a warm wave in fig. 5.)

Figure 1 fully confirms the conclusion advanced by Clayton (4), that a cold wave advances in inclined strata, and that the temperature falls first near the ground, and progressively later at higher altitudes. It is apparent, however, that the rapid fall in temperature is limited to some comparatively low altitude, probably not exceeding 1,000 meters above the ground. The obvious inference that the depth of the strata of rapidly falling temperature shows some coordination with the intensity of the cold wave and the magnitude of its causative HIGH seems well borne out by observation.

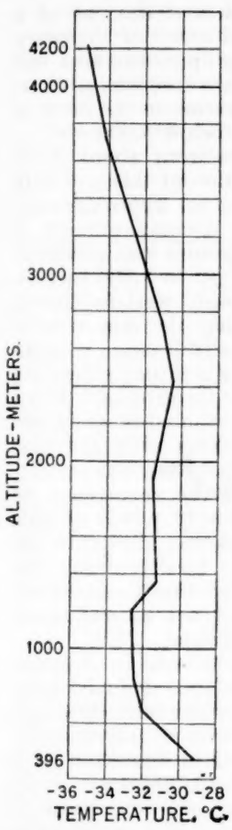

FIG. 2.—Temperature gradient, 11.30 a. m., Jan. 11, 1918, at Drexel.

Vertical temperature gradients at the culmination of a cold wave.—A lag in the rate of temperature fall in the apex of the cold wave probably takes place at some intermediate stage in its progress, while the temperature fall in the higher layers—slow at first—continues steadily till the culmination of the cold wave. The slower fall in the higher altitudes is in accord with the opinion hereinbefore given of the possible origin of cold waves in the lower strata, and the assumed smaller horizontal temperature difference with increasing altitude.

A plausible explanation of the apex of the cold wave becoming first evident near the ground, and later at higher altitudes, is that the cold air can not advance until a temperature gradient to the ground, equal to or less than the adiabatic rate, is established. It is manifestly impossible for a stratum of air that is subject to agitation in a vertical direction to make much horizontal progress, so long as it is potentially colder than the air beneath it. The apex of the cold wave will eventually rise to that altitude in the forward moving stratum of cold air where the wind velocity is the greatest.

If a cold wave, such as depicted in figure 1, culminates at night, the layers of air near the ground, and, to some extent, those of higher altitudes, will cool further by radiation, until a more or less isothermal condition of cold air extending to a considerable altitude, results. Figure 2, taken from the record of free-air observation on January 11, 1918 (5), shows the vertical temperature arrangement on the coldest day of the winter of 1917–18. The observation was taken soon after the crest of a period of rising pressure had passed.

It will be noted that the lowest temperature, −35.1° C., at about 4,200 meters altitude, was but a few degrees lower than the morning surface temperature, although considerably lower than the mean winter temperature for that altitude given in Table 1. Owing to the fact that the winter of 1917–18 was unusually cold, figure 3, taken from the second of the series of diurnal observations on January 27, 1916 (6), is shown as representing a more nearly typical condition. In this graph, the shallow depth of the stratum of low temperature is at once apparent; while at higher altitudes, temperatures appear to be about normal for the season. In the higher altitudes, however, the winds had backed to strong west and southwest, showing that a recovery of temperature had probably already begun, although the surface pressure was still rising. During the observation of January 11, 1918, the winds were from a general northwesterly direction and of gale force from the ground to the highest altitude reached.

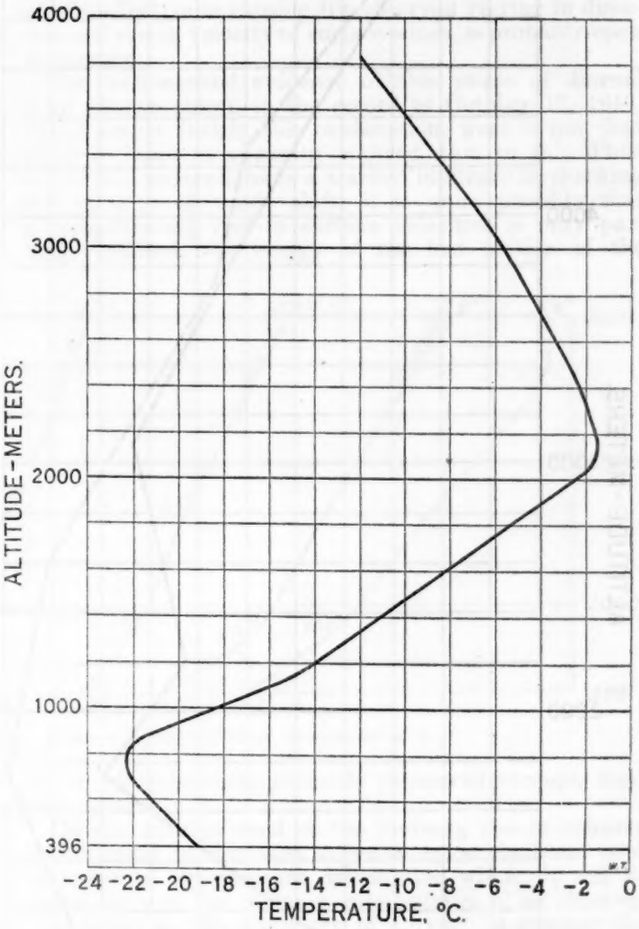

FIG. 3.—Temperature gradient, 11 a. m., January 27, 1916, at Drexel.

It appears that the outstanding feature of cold waves is at first a rapid fall in temperature at moderate altitudes above the ground; and that the fall in temperature in the higher altitudes, and the subsequent fall at all levels depends on the magnitude—but principally on the persistence—of the accompanying HIGH or succession of HIGHS. A persistence of high pressure, or a rapid succession of areas of high pressure, is apparently correlated with a deepening, through radiation, of the already cold masses of imported air.

Presumably, radiation continues to cool the elevated strata during the prevalence of high pressure until low temperatures are reached, after which further cooling of the surface layers to temperatures much below that of the

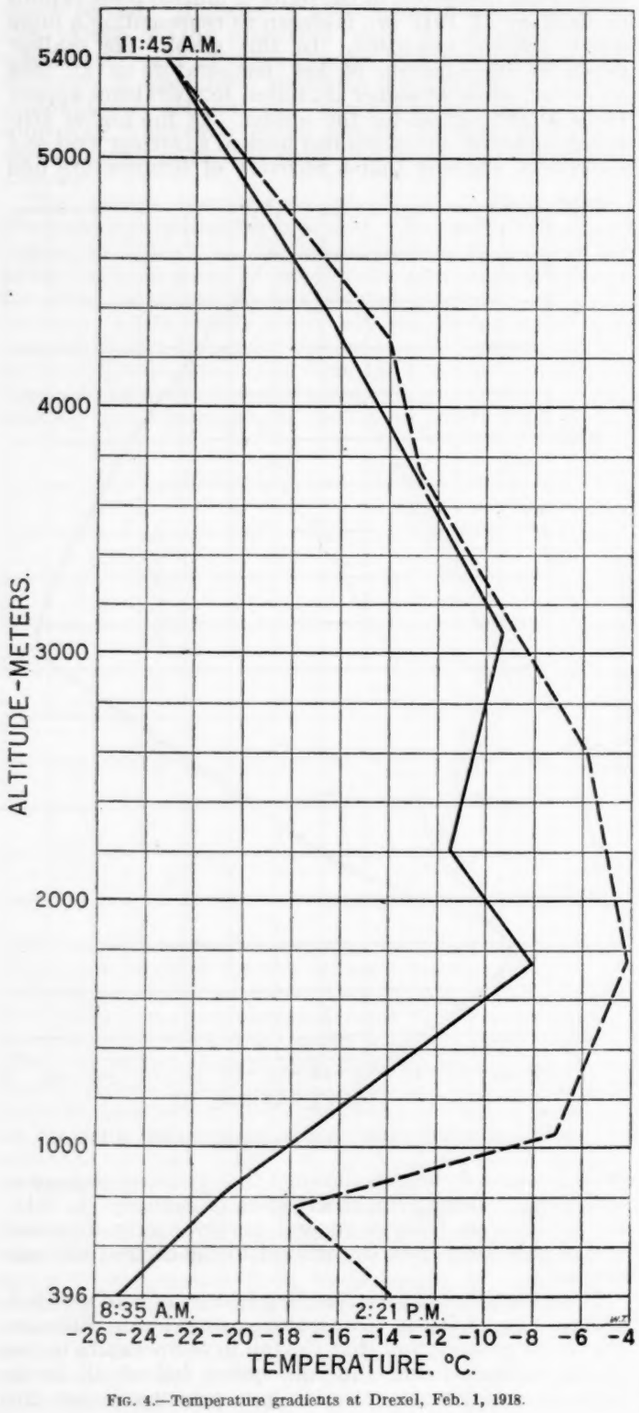

FIG. 4.—Temperature gradients at Drexel, Feb. 1, 1918.

layers aloft is held in check by the fact that the rate of radiation becomes less as the temperature becomes lower. Insolation is therefore effective in limiting the possible minimum temperature on the ground and the layers of air immediately above, when conditions are favorable for prolonged radiation. A vertical temperature gradient such as that shown in figure 2 may be inferred as the final result of persistent high pressure in winter.

Recovery of temperature after a cold wave.—Apparent evidence of dynamic heating of descending air in the crest of a HIGH is occasionally shown when an observation under those conditions is possible at night. The last observations in the diurnal series of January 2–3, 1919 (**7**), made in the crest of a cold high-pressure area showed a rise in temperature in the higher altitudes before insolation had begun or a change in wind direction had taken place.

Figure 4 illustrates an early stage in the temporary recovery of temperature, due to changing winds, during an extended period of cold weather. The graphs show the temperatures during the ascent and descent of a kite in the first flight of the diurnal series of February 1–2, 1918 (**8**), when the crest of a high-pressure area had just begun to recede and a low-pressure area was advancing from the north. A rise in temperature in the interval between ascent and descent is noted below 3,000 meters. being well pronounced in the layers from about 2,500 meters to the ground. An examination of this and subsequent observations extending over an approximately 28-hour period shows that, as an accompaniment of falling pressure, the wind near the ground was generally southwest, while at higher altitudes up to 3,500 meters, the winds that had previously been west-northwest gradually became southwest; also that the rise in temperature below 3,000 meters eventually became concentrated in a sustained relatively warm stratum extending from about 300 to 1,000 meters above the ground. From 3,000 meters to 3,500 meters and presumably at higher altitudes, to which heights observations after the first flight did not extend, the rise in temperature was small.

These conditions, connected with the recurrence on February 3, 1918, of cold northwesterly winds of gale force attending a rapid rise in pressure, illustrate the temporary moderating influence of a LOW bridging two vigorous HIGHS and lead to the inference that the influence of this particular LOW probably did not extend much higher than 3,000 meters above the ground.

Progressive vertical temperature gradients in a warm wave.—In support of the partial evidence deduced from the foregoing that a tendency for an increasingly warm stratum of air to become pronounced at successively lower altitudes is perhaps as typical of the front of a LOW as the characteristic rise in temperature itself, figure 5, taken from the diurnal series of observations of October 16–17, 1917 (**9**), is produced. This graphically shows the progress of a warm wave that became evident in the early evening hours, or about 12 hours after a fall in pressure set in. An over-running warm current, of which this is a good example, is discernible as a rule only in night or early morning observations, particularly in clear weather, as the warming effect of convectional currents tend to mask other causes of rising temperature by day.

It will be noted that this warm wave first became evident principally at about 1,000 meters above the ground, from which altitude the apex of the advancing current of rising temperature gradually descended to about 400 meters. The combined effect of rising temperature aloft and cooling by radiation in the layers near the ground in causing a steep inverted gradient is significant of the small tendency of warm air aloft to intermix with the cooler air below. In such a circumstance clear weather in the morning will cause a rapid rise in temperature on the ground

until the inversion temperature is exceeded, inasmuch as insolation will then be available to heat, through the medium of convectional currents, only the comparatively thin stratum of air comprising the inverted gradient.

Possible characteristic air movement in the front of a LOW.—The altitudinal progress of the warm wave, opposite in direction to that of the cold wave, admits of an easy explanation. It may be assumed that the warm wave represented a south-to-north drainage from a mass of air probably not much more than 1,000 meters deep, that had previously been abnormally warmed by insolation. The well-understood rising of isobaric surfaces in strata above the ground, contingent upon unequal heating or cooling in a horizontal direction, would then cause a flow of warm air from south to north. This flow would be evident first at the altitude of the top of the column, because there the isobaric gradients would be steepest and the wind consequently strongest. The air brought in by the successively lower and slower winds would also be increasingly warmer, as would be expected from a column of air warmed by insolation and convection.

It is apparent that an overflow of air from a warm column does not necessarily imply a return current near the ground, but that under certain conditions the consequence of temperature difference between adjacent columns may be a general movement of air from warmer to colder. The displaced air is undoubtedly compensated by a return current in another more or less remote vertical plane. The warm wave cited occurred in the front of a LOW that advanced from the southwest, but whether it was simply incidental to the circulation in the front of the LOW, or, in view of the possible circumstance offered in its explanation, was a contributing factor to the development of the LOW, is a matter for conjecture. The question of cause and effect in this instance suggests some of the reasons offered by Prof. Bigelow in support of his counter-current theory of storms (**10**).

Cyclonic and seasonal temperature cycles.—If figures 1, 2, and 5, in the order given, be imagined as representing a complete cycle of temperature fall, minimum, and recovery, a seasonal parallel cycle is apparent in Table 2. If the figures in Table 2 be accepted as approximately average gradients, and noting that January is the coldest month, the conclusion is suggested that the inverted gradients in late autumn and early winter are in large part the resultant of under-running cold winds, and in late winter and early spring the resultant of over-running warmer winds. The small inversion rate extending to a considerable altitude in January could be explained in much the same way as the approximately similar vertical gradients in figure 2.

DIURNAL CHANGE IN WIND VELOCITY AND DIRECTION.

An examination of the data contained in the observations from which figure 5 was drawn suggests some comments on the generally accepted explanation of change in surface wind direction and velocity with diurnal change in temperature. That the descending air, reciprocal to the rising currents due to insolation, by retaining much of its original momentum after reaching the ground, is wholly effective in causing the observed veering in direction and rise in velocity of surface winds, is probably open to question.

The well-marked evidence of this phase of diurnal wind change shown in the record of October 17, 1917, would amply justify this explanation, were it not that there is frequent apparent contradiction to it. While convection currents have a marked influence in checking the velocity of winds aloft, it is quite possible that a compensating rise in surface velocities is only partially realized, the energy of the lost motion of the upper currents being probably conserved through thermal changes.

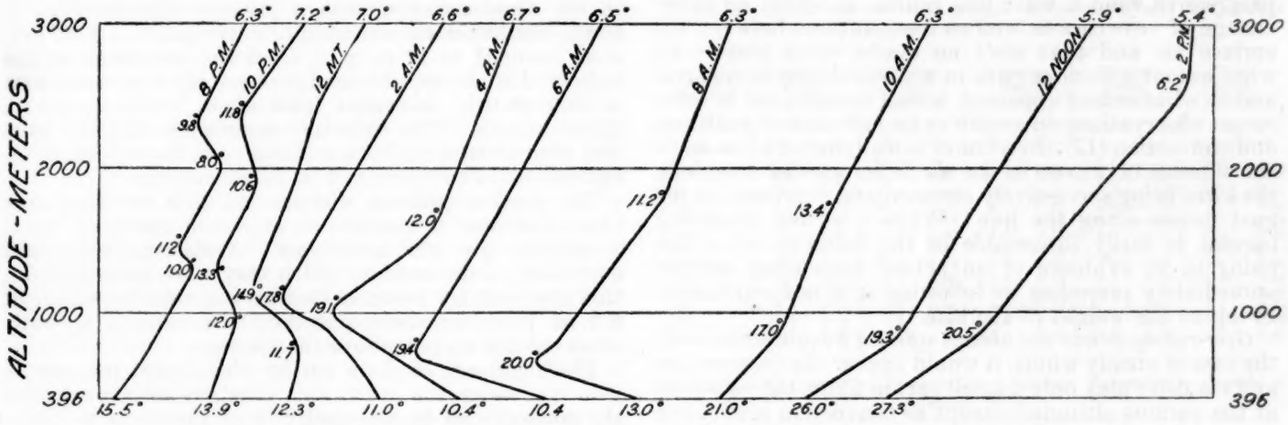

FIG. 5.—Progressive temperature gradients in warm wave of Oct. 16-17, 1917, at Drexel. Temperature in °C.

On the date referred to the morning rise in velocity and veering in direction suggests an explanation connected with the pressure distribution which, it will be noted, showed the common circumstance of an observation taken in the periphery of a LOW. Accepting the supposition that convection currents are a complement to converging circulation in a LOW, in that they aid by removing that surplus upward, it is apparent that on a clear night, convection in the low strata near the ground that have become cooled by radiation being inhibited, converging winds are consequently retarded, if we disregard the influence of friction. With the dispelling of the inverted temperature gradient by insolation, a release of the air via convectional currents is effected in the low strata within the LOW, thereby accelerating the converging circulation. The increased velocity of the converging winds near the ground enables them to veer toward a direction more nearly parallel to the isobars.

Local convection and gustiness.—It is probable that the normal daytime rise in surface wind velocity is also to a large extent due to the independent disturbing

effects of convectional currents, aided by a slight pressure gradient. When conditions favor strong convectional currents, and pressure gradients are weak, kite flights abundantly show that the horizontal currents come in surges at more or less regular intervals, the effect of which on velocity records is largely lost in the ordinary method of registering wind from a Robinson anemometer.

The surges in wind velocity attending convectional currents often show a wide oscillation in direction when the amplitude of the surges is well marked. The oscillations may have a range of 90 or more degrees in azimuth (as, for example, from west to southwest and back again) at intervals a few minutes apart, and tend to be synchronous with the surges in velocity. It is probable that after horizontal currents are once established by convection and pressure gradient their future path is oscillatory, for reasons similar to those given by Sandström in discussing the relation of pressure gradient and wind (**11**). The fact that winds aloft, at even moderate elevations above the ground, change in direction but slowly attests to the comparative freedom of these oscillating convectional winds from influence of the steadier winds aloft.

Convectional currents sometimes appear to give a progressive wind a wave-like course, in which an interchange of velocities as well as temperatures between the surface air and that aloft no doubt takes place. To what extent a sinuous path in a vertical direction is real and to what extent apparent, is well brought out in some recent observations on smoke as an indicator of gustiness and convection (**12**). In a line of kites flying at a low angle the illusion of waves in the air is sometimes complete, the kites being successively elevated and depressed as the gust passes along the line. While a strong ascending current is easily discernible in the behavior of a kite rising in it, evidence of an actual descending current immediately preceding or following it is not conclusive, owing to the weight of the kite.[1]

Over-riding winds not always affected by convection.—In the case of steady winds, it would appear that convection and viscosity play only a small part in fixing the velocities at the various altitudes, except as convection is effective in retarding them. In the morning, an inversion layer near the ground acts as a barrier in limiting convectional currents to the strata intervening between it and the ground, until an adiabatic rate to the ground has been established. That the intensifying of convectional currents is not necessarily productive of higher surface velocity, even when strong winds prevail at a small altitude above the ground, is occasionally shown by kite flights.[2] On the morning of January 9, 1919 (**13**), a free-air observation showed that while the wind velocity a few hundred meters above the ground rose from strong to gale force, the surface velocity fell from light to almost a calm, notwithstanding the fact that the surface temperature rose during the same time. The pressure gradients shown by the morning map of that day were weak over Drexel; also the surface wind did not increase until a steady fall in pressure set in a few hours after the observation. The rise in surface velocity was coincident with a change in direction from northerly to southerly (from the south). It seems conclusive that in this case whatever effect on surface velocity might be attributed to the winds aloft, was an indirect one—that the rather abrupt rise in velocity with altitude observed in the morning contributed to, and was a forerunner of, the fall in pressure that followed.

[1] Evidence of such descending currents is, however, often conspicuously apparent during ascensions with captive balloons. At Mount Weather, Va., such balloons were used on days when kites could not be flown because of light winds, and it was often necessary, especially during summer days, when convection was particularly active, to watch the reel closely, in order that the wire should be let out only at such speed as would enable the balloon at all times to keep the wire taut. Alternately ascending and descending currents produced large variations in this speed, especially at levels between the surface and one or two hundred meters above it; in several instances descending currents were so pronounced as to cause the balloon to drop slightly and the wire to kink, and in two cases a succeeding ascending current, combined with the lift of the balloon, caused the kinked wire to break and the balloon to escape.—W. R. G.

[2] In such cases the temperature of the strong wind is potentially warmer than that at the surface, and, therefore, the convectional columns tend to flatten out against the base of the strong wind rather than to enter it.—C. F. B.

SEA-LEVEL PRESSURE GRADIENT, VERTICAL TEMPERATURE GRADIENT, AND CHANGES IN WIND VELOCITY WITH VARYING ELEVATION ABOVE THE GROUND.

Instances of wind velocities at some moderate altitude decidedly exceeding those called for by mathematical formula applied to sea-level pressure gradients, are quite frequent. Over Drexel such a condition is often connected with a pressure distribution defined by low pressure to the north, and isobars of small curvature extending approximately west-east. Surface winds will then blow from a general southerly direction, while at no great altitude aloft they will be from the west.

The free-air observation of January 26, 1919 (**14**) begun almost simultaneously with the surface observations shown on the morning map of that day, was made in the counterpart of such a pressure distribution. A south-southwest surface wind of between 4 and 5 m. p. s. soon changed to 17 m. p. s. from the southwest at 300 meters altitude, and became successively west-southwest at 600 meters, and west from about 1,000 meters to 3,100 meters. The velocity diminished slightly from 300 meters to about 1,000 meters, above which it increased again to 20 m. p. s. at 3,100 meters.

The surface pressure distribution that morning over Drexel showed a gradient toward the north of about 1 millibar in 120 kilometers. Neglecting the slight curvature of the isobars, which may have been straight, this gradient by formula indicates a velocity of about 6.5 m. p. s., or about one-third the velocity actually observed 300 meters above the ground.

The suggested explanation for the abrupt increase in velocity under the conditions cited, is associated with the general west to east declivity of the western Mississippi Valley and Plains States, and the resultant adiabatic heating, through compression, of currents directed toward the east. If, as a result of this adiabatic heating, the layers of air become warmed, relative to those at the same altitude farther north, the consequent lifting of the isobars over the relatively warmer region will cause steeper gradients toward the north, and increased velocities toward the east. When this condition obtains on a clear night, surface friction and the cooling of the low layers by radiation, will be effective in retarding the velocities near the ground.

The possibility of such a process operating to raise temperatures aloft is suggested in the night observations taken during the diurnal series of December 21–22, 1915 (**15**), although evidence of the rise in temperature being effective in increasing velocities is not conclusive in these observations. A continuous wind from a general westerly direction is noted during the night hours at altitudes ranging from about 300 meters above ground to approximately 1,600 meters. At the base of this west wind, the temperature rose from 4° C. at 6 p. m. to nearly 11° C. at 5:30 a. m.

Abrupt rises in wind force at altitudes coincident with nocturnal inversion levels are frequent, particularly in south winds, and under such circumstances, velocities at some moderate elevation above the ground decidedly

higher than that indicated by surface pressure gradients are not uncommon. A pronounced example is shown in the free-air observation of July 21, 1918 (**16**), in which a rise in velocity from 2.7 m. p. s. on the ground to 25.8 m. p. s. at about 300 meters above the ground was recorded. Surface pressure gradients as shown on the morning map of that day were weak.

Diurnal amplitude in velocity of south winds.—In view of the fact that abrupt rises in velocity at the inversion layer are most frequently observed and most pronounced in south winds, reference is again made to the analysis of the warm wave of October 16-17, 1917, as offering a partial solution. It was early noted at Drexel that following a clear day during which the winds were too light to launch a kite, a kite flight was generally possible in the early evening hours, or as soon as radiation had begun, the possibility amounting to almost a certainty if there had been steady air movement from the south during the day.

An explanation can be reconciled with these observed facts by considering convectional currents as tending to dampen the flow of air by day, and warm air aloft as overrunning the cooler air near the ground at night, unimpeded by vertical currents. If the air movement is from a warmer region, the rise in velocity at and above the inversion layer appears to be due to conditions analogous to the warm wave referred to in the previous paragraph.

When the wind sets in from the south, a period of falling pressure is usually indicated. In the initial stages of falling pressure the winds are likely to be light from some southerly direction, with a tendency to veer with altitude, except that in the lower altitudes stronger winds will be found at night if conditions favor an inversion in temperature. A deepening as well as a strengthening of winds from the south seems to attend the approach of a center of low pressure. The night excess over daytime velocities at moderate elevations above the ground, although probably limited to fair weather, seems to persist until the more vigorous circulation near the center of the LOW checks the effect of convectional currents.

While in the case of a pronounced warm wave, the stratum of maximum temperature change appears to occur in the lower levels and to become progressively lower in altitude—as already pointed out—a slower rise in temperature, extending to higher altitudes, is no doubt an attendant feature. Evidence of this is more especially apparent in summer observations, when a gradient indicating general winds from the south is likely to prevail for a number of days. The conditions discussed in this and the previous paragraph are illustrated in the free-air observations of July 1–3 and September 21–24, 1918 (**17**).

Nocturnal temperature inversion and wind velocity.—Strong winds are often observed at the summit of a nocturnal inversion under circumstances that do not readily admit of the explanation just given, as for instance, when no rise in temperature at the altitude of the strong wind is observed, or when the direction of the wind is other than from the south. In such cases it may be inferred that the velocity indicated by the surface pressure gradient is not attained until an altitude is reached where the air rendered stagnant by radiation is surmounted. The velocity at this inversion level may, moreover, be augmented by a further inclination of the isobars aloft, caused by an unequal cooling in a horizontal direction of the air layers near the ground, or a cooling of columns of air made unequal in height by topography. When the pressure distribution is such that the normal increase in velocity with altitude fails, the effect of nocturnal radiation on velocity is sometimes apparent as a comparatively thin stratum of strong wind near the inversion level, with light winds extending below to the ground, and above to a considerable altitude. The free-air observations on August 26 and 27, 1918, are cited as illustrations.

CONCLUSION.

In the lower air strata it is apparent that causes for deviations from the normal or average vertical temperature gradient are in the main due to changes arising out of cloud formation and dissipation, foehn-like processes, nocturnal radiation, and various modifications in intensity and depth of the cold wave and warm wave phenomena illustrated in figures 1 and 5. Combinations of some of these causes also certainly occur.

The mean temperature gradients in the various quadrants of HIGHS and LOWS for Mount Weather (**18**) seem qualitatively to represent conditions for Drexel as well. It is, however, quite certain that corresponding average winter curves for Drexel will show more pronounced differences in opposing quadrants in both HIGHS and LOWS.

TABLE 1.—*Mean seasonal and annual temperatures and temperature gradients at Drexel, Nebr.*

Altitude, sea level.	Spring. Mean,	Spring. Δt/100m.	Summer. Mean,	Summer. Δt/100m.	Autumn. Mean,	Autumn. Δt/100m.	Winter. Mean,	Winter. Δt/100m.	Year. Mean,	Year. Δt/100m.
Meters.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.	°C.
396	10.3	.....	23.7	.....	11.7	.....	− 6.4	.....	9.8	.....
500	9.6	0.67	23.0	0.67	11.3	0.38	− 6.6	0.19	9.3	0.48
750	7.9	0.68	21.4	0.64	10.2	0.44	− 6.5	−0.04	8.2	0.44
1,000	6.8	0.44	20.1	0.52	9.2	0.40	− 5.6	−0.36	7.6	0.24
1,250	5.8	0.40	18.5	0.64	8.4	0.32	− 4.7	−0.36	7.0	0.24
1,500	4.8	0.40	17.0	0.60	7.6	0.32	− 4.6	−0.04	6.2	0.32
2,000	2.5	0.46	13.7	0.66	5.4	0.36	− 5.3	0.14	4.1	0.42
2,500	− 0.2	0.54	10.2	0.70	2.8	0.52	− 7.1	0.36	1.4	0.54
3,000	− 3.0	0.56	6.8	0.68	0.0	0.56	− 9.5	0.48	− 1.5	0.58
3,500	− 5.9	0.58	3.4	0.68	− 2.8	0.56	−11.9	0.48	− 4.4	0.58
4,000	− 8.8	0.58	0.2	0.64	− 5.5	0.54	−14.6	0.54	− 7.3	0.58
4,500	−12.1	0.66	− 3.1	0.66	− 8.0	0.50	−17.6	0.60	−10.3	0.60
5,000	−15.4	0.66	− 6.3	0.64	−10.6	0.52	−20.8	0.64	−13.3	0.60

TABLE 2.—*24-hour mean temperature gradients, November to March, at Drexel, Nebr.*

Altitude, sea level.	November.	December.	January.	February.	March.
	Δt/100m.	Δt/100m.	Δt/100m.	Δt/100m.	Δt/100m.
Meters.	°C.	°C.	°C.	°C.	°C.
396	.....	.....	.....	.....	.....
500	−1.00	−0.78	−0.19	−1.64	−0.74
750	−0.18	−0.15	0.08	−0.78	−0.16
1,000	0.24	0.05	−0.17	−0.51	0.32
1,250	0.34	−0.38	−0.09	−0.40	0.35
1,500	0.39	−0.02	−0.05	0.01	0.33
2,000	0.56	0.48	0.11	0.40	0.51

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RESULTS OF SOME EMPIRIC RESEARCHES AS TO THE GENERAL MOVEMENTS OF THE ATMOSPHERE.

By H. HILDEBRAND HILDEBRANDSSON.

[Translated by W. W. Reed, Weather Bureau, Atlanta, Ga., January, 1919.]

INTRODUCTION.

A Kepler would not have been possible if a Tycho Brahe had not preceded him. The same thing is true in meteorology. Before it may be possible to study seriously the causes of the general movements of the atmosphere it is necessary first and independently of all preconceived theory to seek to determine with precision what actually takes place in the atmosphere, that is to determine by direct observations what these movements are and what is their nature. From the beginning of dynamic meteorology in the middle of the past century the principal aim of our generation has been to concentrate all our efforts on one objective: the assembling of material sufficiently good and of suitable range, the exercising of our patience in elaborating these elements in the most diverse directions for the purpose of facilitating comprehensive views and the showing of characteristic features.

We shall endeavor to present here the principal results relative to the general movements of the atmosphere attained by empirical researches.

All the representations of the general movements of the atmosphere hitherto published are the results of theoretical considerations more or less ill founded. For a long while we have known rather well the mean direction of the wind at a large number of stations in almost all of the countries of the world and also, thanks to the cooperation of all of the mariners and to the classic works of Maury, of Brault, of Köppen, and of other scholars, our knowledge of the régime of the winds over the seas has been for a long while very much detailed. But the movements of the upper layers of the atmosphere were almost unknown until recently. We knew of the countertrades which had been encountered on the summits of the islands, like Teneriffe in the Atlantic and Mauna Loa in the Pacific. This phenomenon was considered a proof of the law announced by Halley in 1686: The temperature of the air, which depends on the calorific influence of the sun, decreases from the Equator to the poles, now there must exist constantly an upper wind, or equatorial current, blowing from the Equator to the poles, and a lower wind, or polar current, blowing from the poles to the Equator.

In addition there was considered the principle stated by Hadley in 1735: Whatever may be the direction taken by an atmospheric current the terrestrial rotation deviates this current to the right in the Northern Hemisphere, to the left in the Southern.

This principle of Hadley's has been proven by mathematical theory and has been verified by the well known experiments of Foucault and others.

The principle of Halley's has also been admitted by the greater number of meteorologists. Dove did not adopt it. He thought that the countertrade descended at the tropics to the surface of the earth, and the winds from southwest or west prevailing over the seas of the north temperate zone and the corresponding winds from the northwest or west in the Southern Hemisphere were considered by him as extensions of the descended countertrades, the equatorial currents as advancing toward the poles while the polar currents move in opposite direction, from polar regions to tropical ones.

These ideas of Dove's are abandoned, but lately better founded doubts as to Halley's principle have arisen. The important discovery by Teisserenc de Bort that the atmosphere consists of two strata: The troposphere extending from the surface of the earth to the height of 8–10,000 meters and the stratosphere lying above makes a vertical circulation so simple but little probable. In reality all of the troposphere consists of cyclonic and anticyclonic circulations with their ascending and descending currents, and consequently two superposed currents moving in opposite directions can not exist there. In the stratosphere vertical currents do not exist, and the horizontal currents have not been studied. It is true that above the equatorial zone the troposphere rises to very great heights, so that there the stratosphere is found only at heights much greater than in Europe; and also that over the Atlantic north of the equator and, by M. Berson, over Lake Victoria Nyanza cirriform clouds have been observed moving from the southwest at great heights. But even if there were in the stratosphere a general movement from the southwest toward the pole, which would lead to a descending current in the neighborhood of the pole, that would hardly indicate a vertical circulation of the entire atmosphere between the equator and the poles. It must be noted that at the lower limit of the stratosphere over Europe the pressure of the air is slight—200 mm. at the height of 9,600 meters—and at the height at which the stratosphere is found over the equatorial zone the pressure of the air diminishes to 50 mm. (at 17,400 meters), and it is at this height that this supposed equatorial current would begin in the stratosphere. But at this place the mass of the air set in motion is very small in comparison with the total mass of the atmosphere. Now then, a general circulation of the atmosphere according to Halley's principle can not be spoken of.

Recently another very serious objection to this principle has been raised by Sir Napier Shaw and others. They point out that the thickness of the atmosphere is infinitely small relative to the size of the earth. In fact it is relatively of the same thickness as the paper which covers terrestrial globe of ordinary size. A regular, double circulation in a layer so thin seems impossible. It is a wonder if it exists between the Equator and the Tropics.

I.

THE GREAT CURRENTS OF THE ATMOSPHERE INDICATED BY THE MOVEMENT OF CYCLONES AND ANTICYCLONES.

The most regular and dangerous cyclones are the whirling tropical storms moving in a trajectory. Redfield, Reid, Piddington, and other scholars and also the navigators since Dampier, have all observed that the force of the wind is very different on the two sides of the disk whirling in its march. The right side is called the dangerous semicircle and the left side the more easily navigated semicircle. This has been explained by assuming that the cyclone is a whirl carried by a great current of air. In that case it is evident that in the northern hemisphere the motion of the rotation and that of the translation are in the same direction in the right semicircle and opposed in the left semicircle.

In both hemispheres the cyclones move from east to west within the Tropics, deviate to the right in the Northern Hemisphere and to the left in the Southern according to Hadley's principle, and on entering into the temperate zone they move consequently successively toward north, north-northeast, northeast, and east to the north of the equator and toward south, south-southeast, southeast, and east to the south of it. The trajectory is nearly parabolic with the vertex at latitude 20°–30°, according to the season, in the Northern Hemisphere and at latitude 15°–20° over the Pacific Ocean. In the temperate zones the cyclones, or barometric minima, are less regular and their march more variable, but generally toward a point between northeast and southeast. Clement Ley (1876) was the first to study in more complete detail the march of these minima.(**1**) He found that generally the center moves nearly at right angles to the direction in which the isobars are most compact. If the steepest gradient is found to the east, southeast, or south of the center then the depression moves most frequently toward north, northeast, or east, etc. However, if the steepest gradients are found to northwest, north, or northeast of the center, it most frequently remains motionless or moves (ordinarily slowly) in any direction; although a movement toward the west, which should then be found, is in reality very rare.

This fact inspired in Clement Ley this idea, "more simple than correct perhaps," says he, that the direction of the center is the resultant of two independent forces; one, the force of the gradient, which directs the center at right angle to the direction in which the isobars are most compact; another, "a force unknown and a little stronger" than the first, which carries it toward northeast or east.

In studying more in detail the northern portions of the minima (**2**) I have ascertained that the depressions having low pressure to the north are not closed (above) north of the center. But if on the other hand the depression passes to the south of a maximum, the whirl has a more considerable height and is closed even at the north of the center.

This is easily explained by assuming that the depressions are whirls in a current of air moving from west to east. In that case it is necessary that they have with the tropical cyclones a dangerous semicircle on the right and a safer semicircle on the left.

If the current from west to east—"the unknown force" of Clement Ley—is a little stronger than the velocity of rotation north of the center, the movement of the air relative to the surface of the earth will be from west to east. But the velocity of rotation depends on barometric gradient, and that must generally be greater if there is a maximum toward the north, and in that case the chance is greater that the velocity of rotation will exceed that of the current from west to east, but then the whirl is closed to the north of the center. The paths of the minima are more irregular in the Northern Hemisphere because of the irregular distribution of land and sea surfaces, on the other hand in the southern hemisphere "the brave west winds" of the sailors caused by winds from the west at the south of tropical maxima and those at the north of the minima of the temperate zone have extraordinary constancy.

The director of the observatory at Sydney, H. C. Russell, was the first to study the march of anticyclones over the Indian Ocean (**3**) and Australia. He found that the permanent anticyclones indicated on the charts showing mean isobars of the Tropics are caused by a series of anticyclones which pass continually from west to east at almost the same latitudes (the Tropic of Capricorn), in the same way that the low pressure south of Iceland in winter is due to a continuous series of depressions which traverse this part of the North Atlantic Ocean.

The paths are found at 37°–38° south latitude in summer, at 29°–32° latitude in winter.

These studies have been continued by William Lockyer in his interesting treatise on the circulation of the winds of the Southern Hemisphere (**4**). In comparing the barometric curves at two stations situated at almost the same latitude, but at a distance of several degrees of longitude, he was able to determine the time in which the maximum had passed from one station to the other.

From a great number of such measurements he found that the mean velocity per day is:

	Longitude.
Over southern Africa	12°
Over Australia	11.5°
Over South America	11.1°
Over the continents	11.5°

Over the oceans the velocity per day is 9.2° of longitude for all oceans south of the Equator.

An analogous research relative to the minima of barometric waves in the antarctic regions has given for the mean velocity of cyclones nearly the same value, 9°–10° of longitude per day.

Now in the Southern Hemisphere there are two whirl zones, anticyclonic around the Tropic and cyclonic south of latitude 60°. This is in perfect agreement with the charts of mean winds for the Southern Hemisphere. In fact, all around the earth between 40° and 55° south latitude there prevail the "brave west winds," the most constant winds that exist. They result from constant gradients between the maxima at the north and the antarctic minima. The régime of the winds is much more simple over the Southern Hemisphere, almost entirely covered by the oceans, than over the Northern Hemisphere, where the continents cause great perturbations.

Figure 1 (on plate facing p. 391) shows the circulation in the Southern Hemisphere according to William Lockyer.

Hence the study of the paths of cyclones and of barometric minima has proven that there is a constant current from east to west within the Tropics and currents in the contrary direction, from west to east, over the temperate zones.

II.

THE GREAT CURRENTS OF THE AIR AS INDICATED BY THE MEAN DIRECTIONS OF THE CLOUDS.

In order to study the mean directions of the currents of the air at different altitudes above the ground the observations of the movements of the different forms of clouds have been examined. Observations were begun by myself in Sweden in 1873 and somewhat later by Clement Ley in England. Gradually such observations were begun in several countries. But at the beginning the observations were too infrequent, oftentimes their value was questionable and—what was worse—the classification of clouds was different in different countries. Besides it could not be affirmed *a priori* that the mean direction of a certain form of cloud observed was that of the prevailing wind at the same height. In fact in order that the direction of the upper currents might be determined it was first necessary that the clouds should float there, since without this the currents are invisible; then it was necessary that these clouds be not hidden by lower

clouds. Now it is evident that these conditions are not always satisfied.

Despite these hindrances we treated this question in a preliminary manner.

In 1885 (**5**) we discussed as regards Europe the observations of the movements of the upper clouds made at a large number of stations, and in 1889 (**6**) we extended these researches as far as possible over all the surface of the earth. From these well harmonizing results I drew the following conclusions:

1. In the upper regions above the temperate zones there prevail currents whose direction is in the mean from west to east;

2. Within the Tropics their direction is the opposite, or from east to west;

3. The direction of the upper currents seems to coincide almost with the mean path of the centers of barometric depressions.

In February, 1887, R. Abercromby and myself presented two papers before the Royal Meteorological Society in London, in which we proposed a new classification of clouds. The Meteorological Conference at Munich in 1891 recommended this classification as international, and named a commission on clouds, of which I had the honor to be president, to take the measures necessary for the publication of an International Cloud Atlas, in colors and of moderate size and cost (**7**).

At the same time the Conference proposed that measurements of the movements and of the heights of clouds be undertaken for a year at different stations, distributed over the entire earth, and I was asked to prepare the instructions for these observations.

All this preparation having been made, the permanent meteorological committee and the commission on clouds met at Upsala in August, 1894. There had been prepared for this meeting a display containing more than 300 reproductions of clouds—in photographs and in colors—from different parts of the earth. After having chosen the forms to be reproduced in the International Atlas, the commission charged another commission with the publication.

This was composed of H. Hildebrandsson, A. Riggenbach, and Léon Tiesserenc de Bort. In addition the commission determined the description and the definitions of the different forms of clouds, as well as the instructions for the observers. All of the proposals were accepted by the permanent committee, which invited all the meteorological institutions of the world to prosecute observations and measurements of clouds from May 1, 1896, to May 1, 1897, according to the instructions adopted.

As in several countries many stations had not been able to begin the observations on the date fixed at Upsala, the Conference assembled at Paris in 1896 resolved that it would be desirable that the direct observations of clouds be continued at such stations until the close of 1897.

A large number of countries took part in this great enterprise, and the results were published everywhere in the form proposed by the commission on clouds.

I published the principal results of this mass of observations in a report to the International Meteorological Committee. The most interesting part of this report is that on the general circulation of the atmosphere (**8**).

These researches terminated in the following results.

1. *Upper clouds.*

The results found in the papers of 1885 and 1889 are fully verified: In the region of the upper clouds, cirrus and cirro-stratus, the direction of the winds is in the mean from west to east in the temperate zones and from east to west in the tropical zone.

Figure 2 and [omitted] Tables 1 and 2 give the results for some selected stations.

Thus at Blue Hill, near Boston, in America; at Upsala, in Sweden; at Irkutsk, in Siberia; and at Hakodate, in Japan; the wind at the height of the upper clouds has everywhere a direction from west to east with a north or south component according to the season.

On the other hand the upper wind is from the east at the tropical stations: Square 3 lying between the Equator and 10° north latitude and between 20° and 30° west longitude and near Africa, Paramaribo in Dutch Guiana, and San José in Central America.

At Mukimbungo, Congo State, the mean direction of the cirrus clouds is from E. 37° S.

We give in addition for the temperate zone the following data on the mean movement of upper clouds:

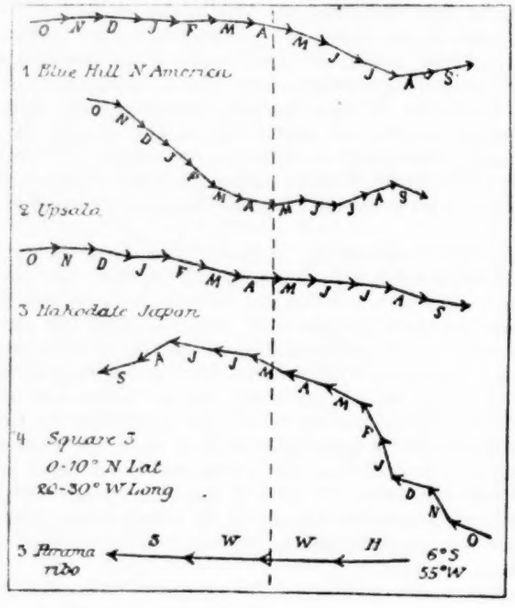

FIG. 2.

TABLE 3.

	Means of all stations		Nora, Sweden, 59° 32′ N.	Tomsk, Siberia, 50° 30′ N.
	England.	Germany.		
January	W. 2° N.	W. 7° S.	W. 49° N.	W. 42° N.
February	W. 10° N.	W. 42° N.	W. 32° N.	W. 50° S.
March	W. 21° N.	W. 11° N.	W. 30° N.	W. 34° S.
April	W. 9° N.	W. 15° N.	W. 12° N.	W. 13° N.
May	W. 5° S.	W. 36° S.	W. 2° N.	W. 73° N.
June	W. 3° N.	W. 8° S.	W. 4° S.	W. 37° S.
July	W. 11° N.	W. 12° S.	W. 8° S.	W. 20° S.
August	W. 5° N.	W. 13° S.	W. 1° S.	W. 22° S.
September	W. 1° N.	W. 6° N.	W. 9° N.	W. 4° S.
October	W. 9° N.	W. 35° S.	W. 14° N.	W. 2° S.
November	W. 15° N.	W. 5° S.	W. 33° N.	E. 70° S.
December	W. 58° N.	W. 2° N.	W. 29° N.	W. 10° S.

2. *The trade wind zone.*

In the Atlantic there is no station situated in the middle of the trade-wind belt, but in the southeast trade wind of the Indian Ocean there is the excellent observatory of Mauritius. In the official report of the director, T. F. Claxton, for 1897 we find the mean monthly directions of the upper clouds and those of the winds for the years 1877–1897. The total number of cloud observations is 3,393.

Table 4 [omitted] and figure 3, B, give results.

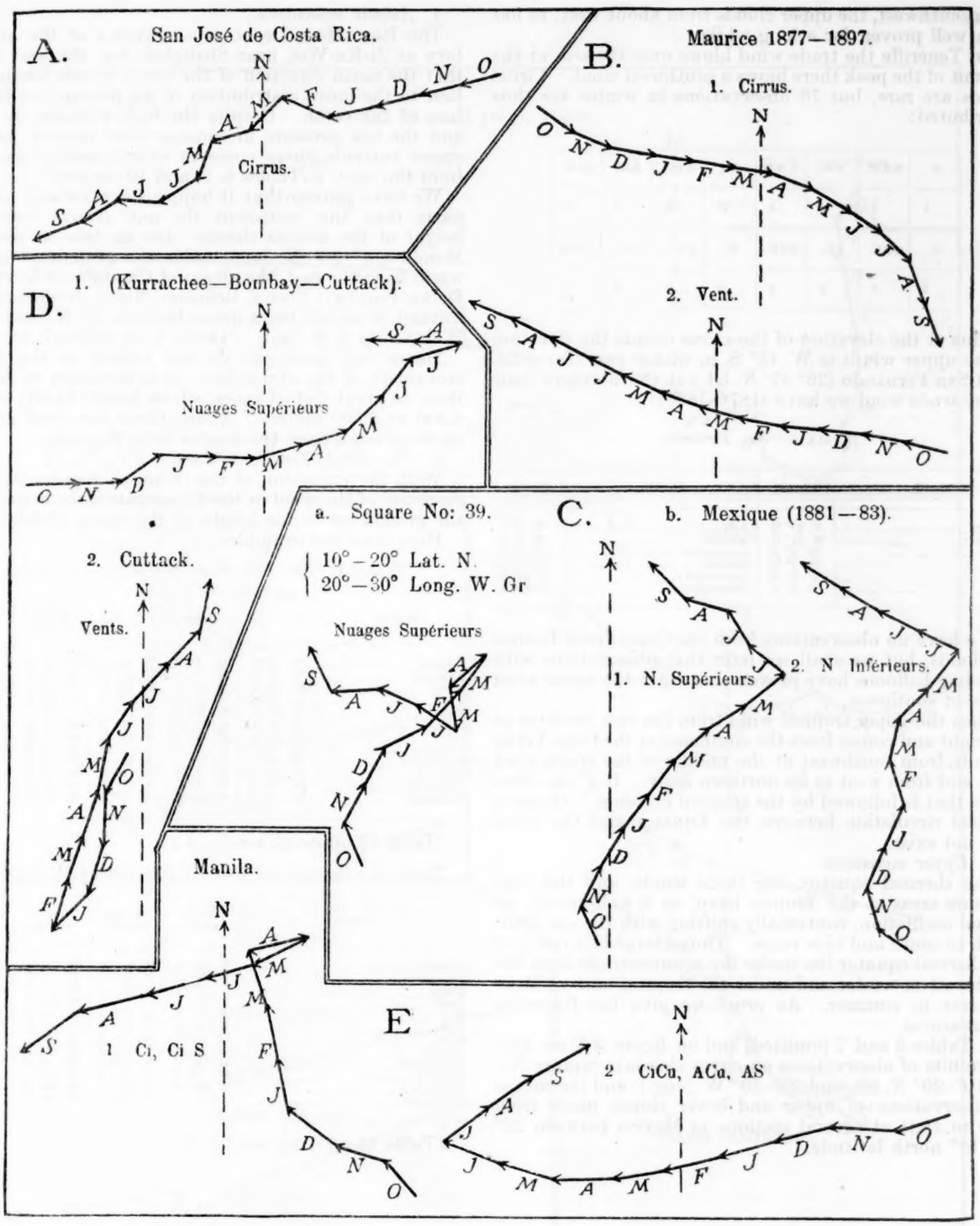

FIG. 3.

Thus in the midst of the southeast trade wind the counter-trade blows nearly from northwest. North of the Equator it should blow from the southwest.

In the theories of Ferrel and J. Thomsen it is stated that the counter-trade continues, at least in large part, as an upper southwest wind as far as the vicinity of the north pole. We shall see that this is not true.

In reality the counter-trade of the northern hemisphere, like all of the winds, deviates to the right and at the polar limits of the trade wind zone has become a west wind. This deviation increases, as is known, with elevation, for an upper wind deviates to the right of a lower current. Above a south wind, for example, the lower clouds move from south-southwest, the intermediate (middle) clouds

from southwest, the upper clouds from about west, as has been well proven for a long while.

On Teneriffe the trade wind blows over the sea, at the summit of the peak there blows a southwest wind. Cirrus clouds are rare, but 76 observations in winter are thus distributed:

N.	NNW.	NW.	WNW.	W.	WSW.	SW.	SSW.
1	1	0	0	27	6	7	2
S.	SSE.	SE.	ESE.	E.	ENE.	NE.	NNE.
5	3	5	3	2	0	2	1

Thus at the elevation of the cirrus clouds the direction of the upper winds is W. 15° S. in winter over Teneriffe.

At San Fernando (36° 37′ N. lat.) at the northern limit of the trade wind we have (1876–1885):

TABLE 5.—*San Fernando.*

Month.	Cirrus.	Month.	Cirrus.
January	E. 30° N.	July	W. 4° S.
February	W. 24° N.	August	W. 3° S.
March	W. 8° S.	September	W. 4° N.
April	W. 7° N.	October	W. 3° N.
May	W. 3° S.	November	W. 20° N.
June	W. 3° N.	December	W. 35° N.

We have no observations from the Cape Verde Islands on clouds, but we shall see later that observations with sounding balloons have proven that there the upper wind is about southeast.

Thus the upper tropical wind from the east deviates to the right and comes from the southeast at the Cape Verde Islands, from southwest at the middle of the trade wind belt, and from west at its northern limit. It is the same curve that is followed by the tropical cyclones. Hence a vertical circulation between the Equator and the poles does not exist.

3. *Upper monsoons.*

The thermal equator, the trade winds, and the high pressure areas at the Tropics have, as is well known, an annual oscillation, continually shifting with the sun from north to south and vice versa. Thus a large belt north of the thermal equator lies under the counter-trade from the southwest in winter and under the tropical current from the east in summer. As proof we give the following observations.

In Tables 6 and 7 [omitted] and on figure 3 C we give the results of observations on cirrus clouds in Square No. 39 (10°–20° N. lat. and 20°–30° W. long.), and the means of observations of upper and lower clouds made from 1875 to 1884 at several stations in Mexico between 23° and 19° north latitude.

4. *Asiatic monsoons.*

The Rev. Marc Dechevrens, director of the observatory at Zi-Ka-Wei, near Shanghai, was the first to find that the mean direction of the cirrus clouds has no relation to the mean distribution of air pressure at the surface of the earth. Despite the high pressure in winter and the low pressure in summer over eastern Asia the upper currents there come in every season constantly from the west. (Tables 8, 9, and 10 omitted.)

We have proven that it happens everywhere in these parts that the monsoons do not always reach the height of the middle clouds. Let us take as examples Manila (14° 36′ N. lat.) under the system of tropical winds from the east, the means of the stations Kurrachee, Deesa, Bombay, Poona, Belgaum, Nipur, Jubbelpore, and Cuttack in central India (mean latitude 20° N.) and Zi-Ka-Wei (31° 11.5′ N. lat). (Tables 8–10 omitted: see fig. 4.)

Hence the monsoons do not belong to the general movement of the atmosphere; it is necessary to consider them as great disturbances, whose height hardly exceeds 4,000 to 5,000 meters. Above them the great currents move as usual from the west or from the east.

5. *The North Temperate Zone.*

With the exception of the monsoon regions the mean direction of the wind in the Temperate Zone is west from the ground up to the height of the upper clouds.

Here are some examples:

TABLE 11.—*Blue Hill, Mass., United States of America.*

Month.	Ci., Ci.-S.	Ci.-Cu.	A.C., A.S.	Lower clouds.	Wind.
January	W. 4° N.	W. 4° S.	W. 19° S.	W. 8° N.	W. 10° N.
February	W. 1° S.	W. 2° S.	W. 16° S.	W. 9° N.	W. 20° N.
March	W. 5° N.	W. 21° N.	W. 27° N.	W. 34° N.	W. 41° N.
April	W. 14° N.	W. 38° N.	W. 7° S.	W. 23° N.	W. 39° N.
May	W. 22° N.	W. 22° S.	W. 16° S.	W.	W. 63° S.
June	W. 28° N.	W. 5° N.	W. 14° S.	W. 8° N.	W. 43° S.
July	W. 20° N.	W. 3° S.	W. 11° N.	W. 9° N.	W. 36° S.
August	W. 4° S.	W. 3° S.	W. 7° N.	W. 5° N.	W.
September	W. 13° S.	W. 14° S.	W. 15° S.	W. 1° N.	W. 11° N.
October	W. 5° S.	W. 5° S.	W. 6° S.	W. 6° N.	W. 18° N.
November	W. 2° S.	W. 3° N.	W. 16° S.	W. 7° N.	W. 7° N.
December	W. 6° S.	W. 14° S.	W. 7° S.	W. 10° N.	W. 11° N.

(Table 12 omitted: see fig. 4.)

TABLE 13.—*Denmark (56° Lat. N.), 1886–1900 (M. H. Nielsen).*

Month.	Upper clouds.	Middle clouds.	Lower clouds.	Wind.
January	W. 39° N.	W. 40° N.	W. 22° S.	W. 42° S.
February	W. 36° N.	W. 39° N.	W. 1° N.	W. 7° S.
March	W. 27° N.	W. 32° S.	W. 5° S.	W. 20° S.
April	W. 15° S.	E. 75° S.	W. 24° N.	E. 60° N.
May	W. 18° S.	W. 44° S.	W. 2° N.	W. 85° N.
June	W. 5° S.	W. 16° S.	W. 8° N.	W. 20° N.
July	W. 10° N.	W. 5° S.	W. 3° S.	W. 16° S.
August	W. 11° S.	W. 37° S.	W. 17° S.	W. 33° S.
September	W. 4° N.	W. 17° S.	W. 9° S.	W. 10° S.
October	W. 6° S.	W. 10° S.	W. 36° S.	W. 53° S.
November	W. 30° N.	W. 20° S.	W. 50° S.	W. 54° S.
December	W.	W. 18° S.	W. 42° S.	W. 57° S.

(Table 14 omitted: see fig. 4.)

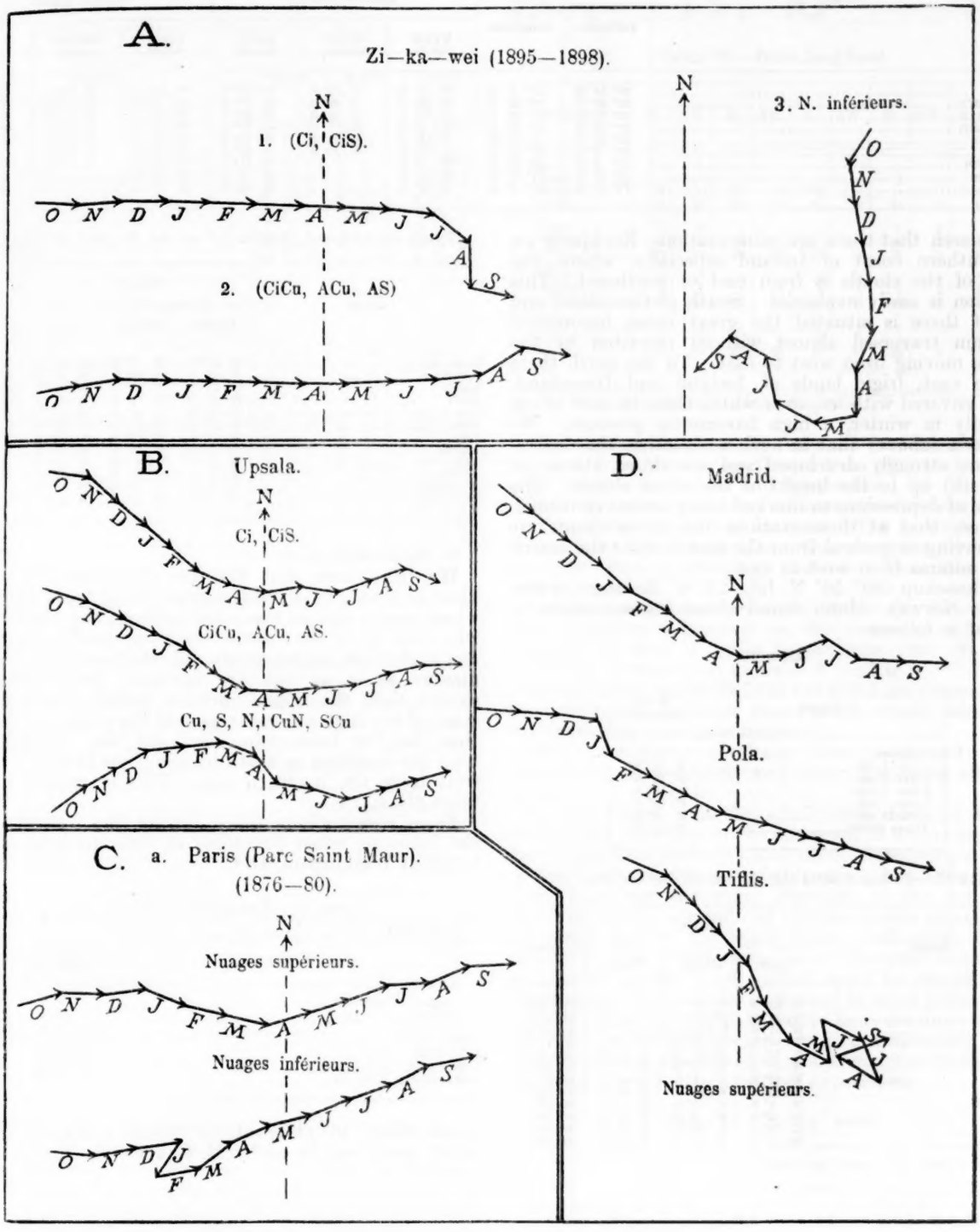
A.
Zi—ka—wei (1895—1898).
N
1. (Ci, CiS).
O N D J F M A M J J A S
2. (CiCu, ACu, AS)
O N D J F M A M J J A S
N
3. N. inférieurs.
O N D J F M A M J J A S
B. Upsala.
N
Ci, CiS.
O N D J F M A M J J A S
CiCu, ACu, AS.
O N D J F M A M J J A S
Cu, S, N, CuN, SCu
O N D J F M A M J J A S
D. Madrid.
O N D J F M A M J J A S
N
Pola.
O N D J F M A M J J A S
Tiflis.
O N D J F M A M J J A S
Nuages supérieurs.
C. a. Paris (Parc Saint Maur).
(1876—80).
N
Nuages supérieurs.
O N D J F M A M J J A S
Nuages inférieurs.
O N D J F M A M J J A S

FIG. 4.

TABLE 15.—*March of the clouds over Norway, Iceland, and Greenland.*

	Latitude.	Longitude.	April–September.			October–March.		
			Upper clouds.	Middle clouds.	Lower clouds.	Upper clouds.	Middle clouds.	Lower clouds.
Lödingen	68° 24′ N.	16° 1′ E.	W. 63° S.	W. 75° S.	W. 54° S.	W. 51° S.	W. 60° S.	W. 49° S.
Drontheim	63° 26′ N.	10° 22′ E.	W. 25° S.	W. 46° S.	W. 28° S.	W. 2° N.	W. 9° S.	W. 2° S.
Aasnes	60° 37′ N.	11° 58′ E.	W. 18° S.	W. 15° S.	W. 80° S.	W. 32° N.	W. 24° S.	E. 53° S.
Christiania	59° 55′ N.	10° 43′ E.	W. 9° S.	W. 9° S.	E. 71° S.	W. 30° N.	W. 29° S.	E. 43° S.
Thorshavn	62° 25′ N.	6° 45′ W.	W. 55° S.	E. 25° S.	W. 25° S.	W. 20° S.	W. 70° S.	W. 26° S.
Reykjavig	64° 9′ N.	21° 55′ W.	E. 70° N.	W. 80° S.	E. 57° S.	E. 50° N.	E. 60° S.	S.
Stykkisholm	65° 5′ N.	22° 46′ W.	W. 3° N.	.....	W. 81° S.	W. 43° N.	.....	W. 76° S.
Teigarhorni	64° 40′ N.	14° 19′ W.	W. 29° N.	.....	W. 3° S.	W. 70° N.	.....	W. 23° S.
Upernivik	72° 47′ N.	56° 7′ W.	W. 86° N.	.....	W. 59° S.	E. 2° S.	.....	E. 46° N.

It is seen that there are some stations, Reykjavig on the southern coast of Iceland especially, where the march of the clouds is from east or northeast. This exception is easily explained. South of Greenland and Iceland there is situated the great mean barometric minimum traversed almost without cessation by the minima moving from west to east. To the north there lie the vast, frigid lands of Iceland and Greenland, always covered with ice, over which there is most often, especially in winter, a high barometric pressure. We have seen (above) that in such a situation the depressions are strongly developed and are closed above (at the north) up to the height of the cirrus clouds. The passage of depressions so marked being almost continual, it follows that at these stations the cirrus clouds are seen moving in general from the east despite the march of the minima from west to east.

At Bossekop (69° 56′ N. lat., 23° 8′ E. long.), a station in Norway, Mohn found cloud measurements in 1896–97 as follows:

TABLE 16.

Height.	Wind direction.
Meters.	
0- 1,000	W. 23° N.
1,000- 3,000	W. 12° S.
3,000- 5,000	W. 12° S.
5,000- 7,000	W. 12° S.
7,000-10,000	W. 9° S.
Above 10,000	W. 13° N.

TABLE 17.—*Tomsk, Siberia (56° 30′ lat. N., 84° 30′ long. E.).*

Month.	Clouds.			Wind.
	Upper.	Middle.	Lower.	
January	W. 42° N.	W. 28° N.	W. 5° S.	W. 32° S.
February	W. 50° S.	W. 23° S.	W. 14° S.	W. 85° S.
March	W. 34° S.	E. 24° S.(?)	W. 48° S.	E. 52° S.
April	W. 13° N.	W. 3° S.	W. 13° S.	W. 59° S.
May	W. 73° N.	W. 16° N.	W. 39° N.	W. 3° S.
June	W. 37° S.	W. 8° N.	W. 22° S.	W. 49° S.
July	W. 20° S.	W. 19° S.	W. 54° S.	E. 24° S.
August	W. 22° S.	W. 15° S.	W. 28° S.	W. 66° S.
September	W. 4° S.	W. 13° S.	W. 7° S.	W. 52° S.
October	W. 2° S.	W. 9° S.	W. 21° S.	W. 59° S.
November	E. 79° S.	W. 45° S.	W. 35° S.	W. 72° S.
December	W. 19° S.	W. 19° N.	W. 14° S.	W. 62° S.

TABLE 18.—*Irkoutsk, Siberia (52° 16′ lat. N., 104° 10′ long. E.)*

Month.	Clouds.			Wind.
	Uupper.	Middle.	Lower.	
January	W. 45° N.	W. 7° N.	W. 29° N.	W. 5° N.
February	W. 45° N.	W. 24° N.	W. 45° N.	E. 36° S.
March	W. 45° N.	W. 32° N.	W. 28° N.	E. 78° N.
April	W. 16° N.	W. 14° N.	W. 32° N.	E. 33° S.
May	W. 40° N.	W. 41° N.	W. 45° N.	W. 23° N.
June	W. 11° N.	W. 27° N.	W. 33° N.	E. 80° S.
July	W. 27° N.	W. 27° N.	W. 53° N.	W. 65° S.
August	W. 13° N.	W. 45° N.	W. 34° N.	W. 24° S.
September	W. 22° N.	W. 27° N.	W. 28° N.	W. 14° N.
October	W. 27° N.	W. 34° N.	W. 39° N.	W. 34° N.
November	W. 45° N.	W. 34° N.	W. 42° N.	W. 41° N.
December	W. 45° N.	W. 45° N.	W. 51° N.	W. 69° N.

6. *Subtropical zone.*

We have seen that the air above the Temperate Zone is drawn in a vast whirl turning from the west, whose center lies in the polar regions; and that in this whirl the air in the lowest strata approaches the center and that of the higher strata departs from it in the same manner as in an ordinary cyclone. Hence we must expect that the upper currents invade the northern slope of the high pressure region of the tropics, which will thus be fed from two sides: by the counter-trade from the southern side and by a current from the northwest from the northern side. This is precisely what takes place.

From observations taken during the "cloud year" the following mean directions at different heights were found at Washington, D. C.

TABLE 19.—*Washington (38° 53′ lat. N.).*

Height.	April–September.	October–March.
Meters.		
0-1,000	N. 42° W.	S. 71° W.
1,000-3,000	N. 66° W.	N. 87° W.
3,000-5,000	N. 84° W.	S. 79° W.
5,000-7,000	N. 89° W.	S. 80° W.
7,000-10,000	N. 80° W.	N.
Above 10,000	N. 77° W.	N. 79° W.

According to observations taken a Fayal, Azores, which were sent to us by M. Chaves, the march of the

cirrus clouds is from the northwest in summer and from west-southwest in winter. In winter Fayal lies in the wind system of the Temperate Zone.

TABLE 20.—*Perpignan, France (42° 41′ lat. N.).*

Month.	Upper.	Middle.	Lower.
January	W. 34° N.	W. 37° N.	W. 52° N.
February	W. 39° N.	W. 33° N.	W. 36° N.
March	W. 32° N.	W. 33° N.	W. 24° N.
April	W. 31° N.	W. 40° N.	W. 30° N.
May	W. 28° N.	W. 28° N.	W. 18° N.
June	W. 18° N.	W. 13° N.	W. 10° N.
July	W. 17° N.	W. 22° N.	W. 27° N.
August	W. 23° N.	W. 14° N.	W. 18° N.
September	W. 11° N.	W. 17° N.	W. 12° N.
October	W. 15° N.	W. 4° N.	W. 14° N.
November	W. 34° N.	W. 29° N.	W. 26° N.
December	W. 27° N.	W. 33° N.	W. 32° N.

TABLE 21.—*Cirrus.*

Month.	Madrid (40° 23′ lat. N.).	Pola (41° 22′ lat. N.).	Tiflis (41° 22′ lat. N.)
January	W. 46° N.	W. 77° N.	W. 50° N.
February	W. 22° N.	W. 25° N.	W. 70° N.
March	W. 44° N.	W. 25° N.	W. 56° N.
April	W. 20° N.	W. 27° N.	W. 25° N.
May	W. 6° S.	W. 12° N.	.....
June	W. 23° S.	W. 25° N.	W. 28° N.
July	W. 32° N.	W. 12° N.	W. 65° N.
August	W.	W. 20° N.	.....
September	W. 1° N.	W. 10° N.	W. 21° S.
October	W. 37° N.	W. 8° N.	W. 22° N.
November	W. 36° N.	W. 3° N.	W. 50° N.
December	W. 35° N.	W. 10° N.	W. 43° N.

According to Dallas the march of the cirrus clouds over the Gulf of Persia is from the northwest at all seasons.

7. *Polar regions.*

In the polar regions of the northern hemisphere observations of cloud movement are very rare. The Arctic expeditions are generally old, and then such observations were not yet general. During the "polar year," August, 1882–August, 1883, the mean direction of the upper clouds, cirrus and cirro-stratus was as follows:

	October-March.	April-September.
Jan Mayen, 71° N. lat. (Sobieczky)	W. 23° N.	W. 38° S.
Cape Thorsden, 78° 28′ N. lat. (Ekholm)	W. 55° N.	W. 7° S.

At the most northern station, Treuremberg Bay, on the northern coast of Spitzbergen (79° 59′ N. lat.) J. Westman found from July 1899 to August 1900:

Clouds.	October-March.	April-September.
Upper	W. 2° N.	W. 75° S.
Middle	W. 30° S.	W. 72° S.
Lower	W. 6° S.	W. 48° S.

We shall give the results of the Norwegian polar expedition by Nansen, 1893–1896, which moved with the ice from east to west, from the vicinity of Behring Strait as far as Spitzbergen, and the polar expedition by Zeigler to Franz Josef Land. The expedition sojourned at Cape Flora (80° N. lat., 50° E. long.) from May 21 to August 31, 1904, and at Teplitz Bay (81.5° N. lat., 58° E. long.). We have made calculations as if the observations were made at the same station.

Nansen polar expedition of 1893–1896.

Cirrus	S. 15° E.	Ci-Cu	N. 46° W.
Ci-St	N. 66° W.	Nb (lower)	N. 60° W.
Ci and Ci-St	N. 76° W.	Wind	S. 23° E.

TABLE 22.—*Franz Josef Land.*

Nuages.	N.	NE.	E.	SE.	S.	SW.	W.	NW.	NE.+E.+SE.	SW.+W.+NW.
Winter:										
Upper	.....	.....	6	1	.....	.....	2	1	7	3
Middle	2	.....	10	3	2	.....	.....	.....	15	0
Lower	5	16	33	42	27	9	24	4	91	37
Spring:										
Upper	3	3	1	.....	.....	1	6	1	4	8
Middle	2	6	8	4	.....	.....	4	1	48	5
Lower	10	24	36	38	13	14	27	25	98	66
Summer:										
Upper	3	10	6	1	3	4	4	5	17	13
Middle	2	3	4	6	1	1	6	2	13	9
Lower	10	39	50	53	7	9	29	42	142	80
Autumn:										
Upper	4	2	6	.....	.....	1	2	.....	8	3
Middle	1	3	5	6	2	1	1	.....	14	2
Lower	16	29	67	63	29	20	19	9	159	48

Wind: Dec.–Feb., E. to S.; Mar.–Apr., E. to N. (Teplitz); Oct.–Apr., E. to NE., May–July, W. to NW., Aug.–Sept., variable (Cape Flora).

The winds were generally from the east from October to April, from west to northwest from May to July, and very variable in August and September.

Now the wind was from an easterly direction except in Franz Josef Land in summer. The most frequent direction of the clouds there was also that of east to southeast with a secondary maximum from the northwest in summer.

On the North American expedition of the *Fram*, Capt. Otto Sverdrup sojourned on the coasts of Ellesmere Land to the west of Baffin Bay in 1898–1902 (**9**). The results are summarized in Table 1 (omitted).

At all elevations winds from the north are generally the most frequent and after these, south winds, which are the prevailing ones in summer.

Only two classes of clouds were considered: Upper (cirrus and cirro-stratus) and lower (including all other forms).

It was feared that the winds were deviated by the north-south direction of the strait which separates Ellesmere Land from Heiberg Land, the stations being situated at the southern entrance of this strait, but according to Capt. Sverdrup the same direction of the wind was observed on the summits of the mountains surrounding the strait and as the winds from north-south have a maximum even at the elevation of the upper clouds this irregularity in the wind system must be accepted—an irregularity which will be explained in what follows.

Observations from the Antarctic Zone are more numerous. In the following tables we give a summary of the observations on the march of clouds and the direction of the wind made by the principal expeditions:

TABLE 23.—"*Scotia*," *winds.*

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
1. Cape Pembroke (51° 41′ lat. S., 57° 42′ long. W.)	19.3	9.9	2.8	2.3	4.9	12.8	22.6	25.1
2. Laurie Island, S. Orkney (60° 43′ lat. S., 44° 39′ long. W.)	10.9	2.7	2.1	9.5	9.1	12.5	11.1	36.1
3. Two cruises on Weddel Sea	15	17	9	9	7	12	12	13

February and March, 1903, and March, 1904, calms 6 per cent.

The 3 winds from the east were observed only south of latitude 60° S.

TABLE 24.—*"Snowhills" march of clouds and winds (64° 22′ lat. S. 56° 69′ 45″ long. W.).*

	Ci,CiSt.	CiCu, ACu,ASt.	St.Cu. Nb, St.	Wind, per cent.	
N	0	2	6	0.8	
NNW	0	3	7	0.2	
NW	2	4	6	0.3	
WNW	2	8	6	0.4	
W	11	16	15	0.4	
WSW	3	4	7	12.5	54.5
SW	4	9	13	21.6	
SSW	1	6	3	20.4	
S	1	2	3	4.9	
SSE	0	1	2	0.7	
SE	0	2	0	0.9	
ESE	0	0	1	0.6	
E	0	0	3	2.1	
ENE	0	1	1	3.9	
NE	0	4	3	8.7	
NNE	0	0	4	4.5	
Total	24	62	80	(1)	

[1] Calm 14.8, variable 2.3.

TABLE 25.—*"Gauss" winds, per cent (66° 2′ lat. S., 89° 38′ E.).*

N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.
0.1	0.2	0.5	3.9	47.8	10.5	4.5	4.8

S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.	Calms.
2.0	1.1	1.4	3.4	6.3	1.7	0.9	0.2	10.7

Components in per cent (calms omitted).

	Lat. S.	Long. E.	From E.	From W.
Kerguelen	49° 25′	69° 53′	5.4	90.3
Heard Island	53° 8′	73° 34′	20.5	73.8
"Gauss"	66° 2′	89° 38′	73.3	16.0

TABLE 26.—*"Belgica," cruise from 69° 38′ to 71° 36′ lat. S., 80° 30′ to 96° 40′ long. W.*

Winds.	N.	NNE.	NE.	ENE.	E.	ESE.	SE.	SSE.
Winter	249	226	260	131	181	184	142	123
Summer	132	147	380	504	502	408	334	228

Winds.	S.	SSW.	SW.	WSW.	W.	WNW.	NW.	NNW.
Winter	198	94	284	254	621	389	323	24
Summer	177	132	200	262	215	133	105	84

TABLE 27.—*"Southern Cross," Cape Adare 71° lat. S., 170° long. E.*

	N.	NE.	E.	SE.	S.	SW.	W.	NW.	Calms.
Winds, per cent	3.6	26	9.1	20.4	13.9	4.1	3.1	3.1	40.1
			43.4						

TABLE 28.—*"Discovery," Ross Island, 77° 50′ lat. S., 166° 45′ long. E.*[1]

	N.	NE.	E.	SE.	S.	SW.	W.	NW.
Upper clouds, per cent	8	4	6	8	10	26	19	19
						64		
Smoke from Mt. Erebus (13,000 feet), per cent	4	2	4	8	12	36	28	6
						76		
Lower clouds, do	18	10	13	14	18	15	4	8
					47			
Winds, do	11	20	44	16	6	1	0	2
			80					

[1] National Antarctic Expedition, 1901–1904, Pt. I, p. 495.

8. *Barometric maximum of the North Atlantic Ocean.*

The movements of the upper layers of air over the barometric maximum of the North Atlantic being of the highest importance for our understanding of the general movements of the atmosphere, we have studied these specially.(**10**)

For this study we have used, in addition to the results given above, the nephoscopic observations in the Antilles published by Bigelow (**11**) and those of Chaves from Horta, island of Fayal (Azores).(**12**) Then we have calculated the means of the observations of upper clouds published by Toynbee in 1876 for squares 38, 39, 40, 2, 3, 4, 301, 302, and 303.

The results are entered on the two charts (figs. 6 and 7) on which the directions of the upper currents seem to appear very much in their general characteristics.

Above the equatorial regions the great upper current from the east is very well indicated. Above Cape Verde it moves from the southeast, afterwards becoming the southwest counter-trade over the southern slopes of the barometric maximum, and finally, deviated more and more to the right, it blows from the west over the crest of the maximum.

In the Antilles, where the trade wind blows from east or east-northeast, the upper currents have a direction entirely opposite. This has been known for a long time from the fact that the ashes of the Antillean volcanoes always fall to the east of the volcanoes.

Bigelow has published the observations in graphs. We reproduce here (fig. 5) one of these plates containing the means of four stations. There is clearly seen the opposition between the lower and the upper currents and also the irregular course of the middle clouds between these the two currents.

North of the barometric maximum, in the subtropical zone the upper winds move generally from northwest or from west-northwest as we have seen above.

Farther to the south, over Ascension Island, the cirrus clouds come from the northeast, which corresponds to their course from southeast at Cape Verde.

The charts show the variations of the upper winds with the seasons, the barometric maximum being most to the north in summer and most to the south in winter.

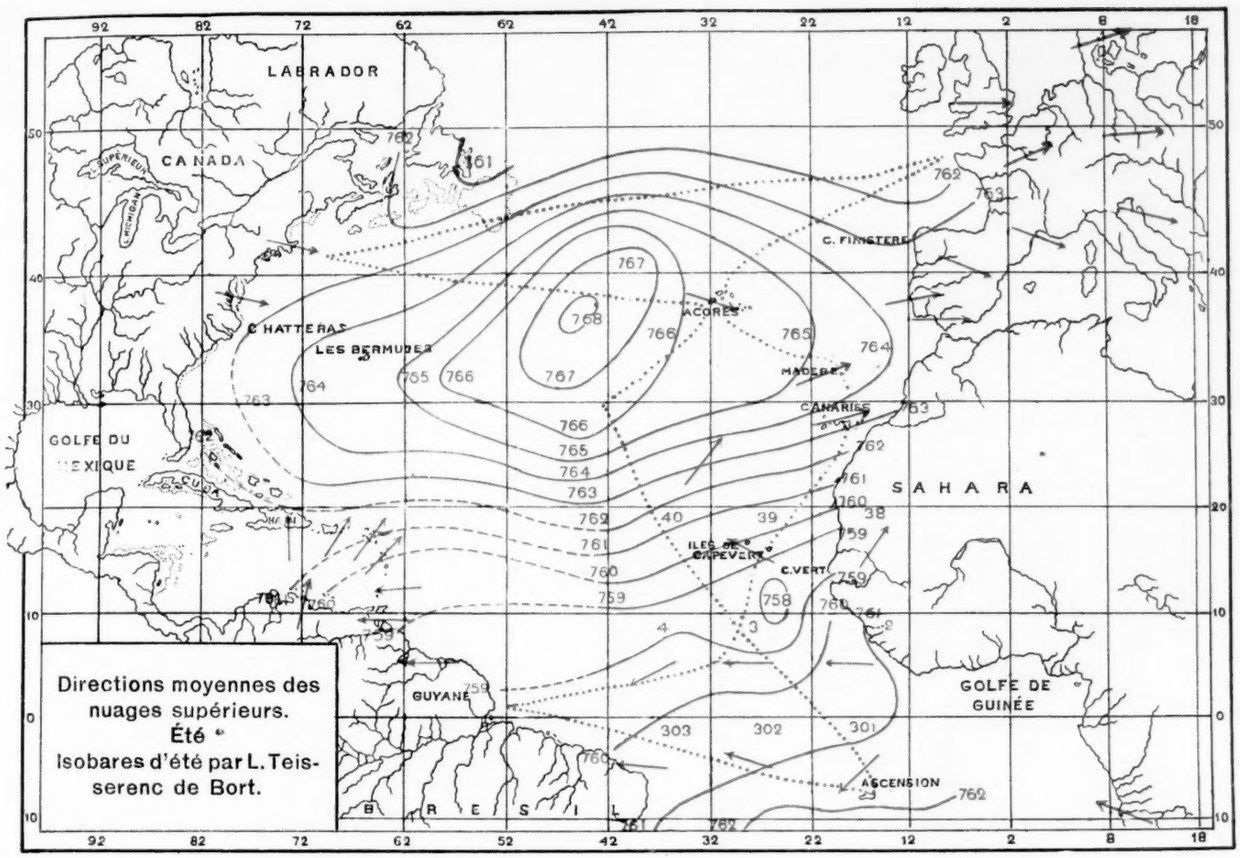
LABRADOR
CANADA
SUPERIEUR
MICHIGAN
C. FINISTERE
C HATTERAS
LES BERMUDES
ACORES
MADERE
CANARIES
GOLFE DU MEXIQUE
CUBA
SAHARA
ILES DU CAPEVERT
C.VERT
GUYANE
GOLFE DE GUINÉE
ASCENSION
B R E S I L
Directions moyennes des nuages supérieurs.
Été
Isobares d'été par L. Teisserenc de Bort.

FIG. 6.

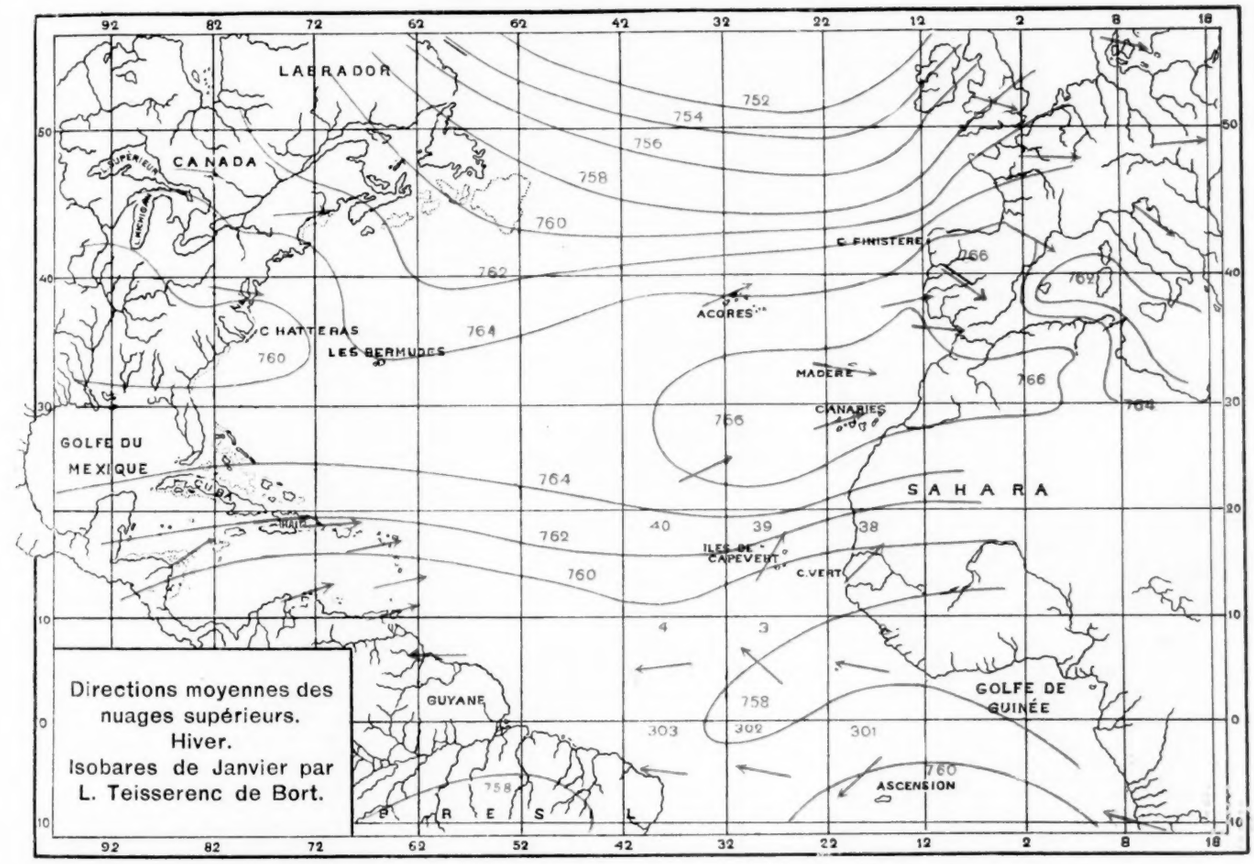
LABRADOR
CANADA
SUPERIEUR
MICHIGAN
C. FINISTERE
C HATTERAS
LES BERMUDES
ACORES
MADERE
CANARIES
GOLFE DU MEXIQUE
CUBA
SAHARA
ILES DU CAPEVERT
C.VERT
GUYANE
GOLFE DE GUINÉE
ASCENSION
B R E S I L
Directions moyennes des nuages supérieurs.
Hiver.
Isobares de Janvier par L. Teisserenc de Bort.

FIG. 7.

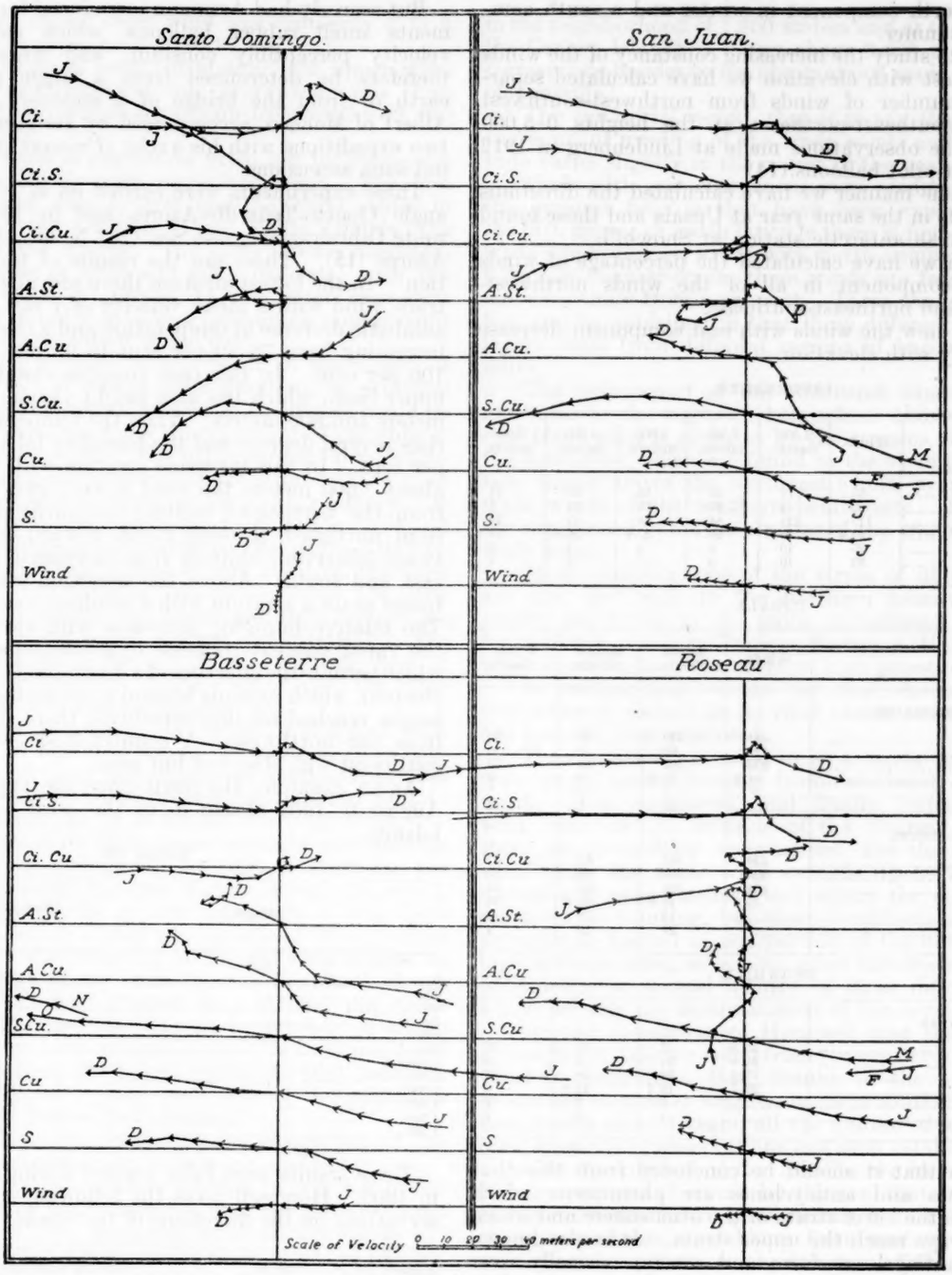

FIG. 5.

III.

AERONAUTICAL OBSERVATIONS.

1. *Temperate zone.*

It is well known that balloons floating at considerable heights move in general from west to east. The greater the height, the more constantly do the winds move toward the east. This is proven almost every day at all the aerial observatories of Europe and America.

Let us cite merely as an example the flights during the Franco-Swedish expedition at Kiruna, latitude 68° N., in Swedish Lapland, organized by my lamented friend, Léon Teisserenc de Bort, and myself.(13)

There during March, 1907, February and March, 1908, and August, 1909, 72 balloons were sent up of which 47 were recovered.

Of these balloons there were only 3 which fell on a meridian to the west of Kiruna; one, after having risen to 10 kilometers, fell almost at the same place at which it was set free; but all of the others fell to the east of Kiruna at greater or lesser distances—some as far as Finland, several hundred kilometers from the point of departure. Like upper clouds the direction had in

general a north component in winter and a south component in summer.

In order to study the increasing constancy of the winds from the west with elevation we have calculated separately the number of winds from northwest-southwest and from southeast-northeast at the heights 0–5,000 meters in the observations made at Lindenberg in 1912 by means of pilot balloons.(**14**)

In the same manner we have calculated the directions of the clouds in the same year at Upsala and those found at the Swedish antarctic station at Snowhill.

And then we have calculated the percentage of winds with east component in all of the winds northwest-southwest and northeast-southeast.

It is seen how the winds with east component decrease considerably with elevation.

LINDENBERG.

	Winds.	1,000 meters.	2,000 meters.	3,000 meters.	4,000 meters.	5,000 meters.
NW-SW	65	78	59	42	30	21
SE-NE	52	43	25	16	11	8
Total	117	121	84	58	41	29
Per cent	44.4	35.5	29.8	27.6	26.8	27.6
N	25	10	8	5	4	2
S	22	10	9	7	2	1

UPSALA.

	Winds.	Lower clouds.	Middle clouds.	Upper clouds.
JANUARY–MARCH.				
NNW-SSW	531	139	49	33
SSE-NNE	422	60	0	0
Total	953	199	49	33
Per cent	44.4	30.2	0	0
N		7	2	5
S		25	1	0
JUNE–AUGUST.				
NNW-SSW	438	165	62	57
SSE-NNE	426	159	29	27
Total	864	324	91	84
Per cent	49.3	49.6	31.9	32.1
N		15	1	3
S		29	10	4

SNOWHILL.

	Winds.	Lower clouds.	Middle clouds.	Upper clouds.
YEAR.				
NNW-SSW	55.8	57	50	23
SSE-NNE	21.4	14	8	0
Total	77.2	71	58	23
Per cent	27.7	19.7	13.8	0
N		6	2	0
S		3	2	1

It seems that it should be concluded from this that the cyclones and anticyclones are phenomena which originate in the lower strata of the atmosphere and which do not always reach the upper strata. It is also known that the anticyclones form and remain normally over cold, dry lands, while the minima form most often over the seas.

2. *Barometric maximum of the North Atlantic Ocean.*

As we have seen, the currents of air above and around the barometric maximum of the Tropic of Cancer are very complicated, but also very interesting to know, if it is desired to study the general movements of the atmosphere. So, hardly had Rotch succeeded in sending kites from a steamer when I proposed to him in 1901 the making of such experiments over this part of the ocean. However, this program was too difficult to be carried out at that time. On one hand the expenses were very considerable and on another the kites did not generally rise to sufficient heights.

But scarcely had Assmann introduced for these experiments small rubber balloons, which ascend with a velocity perceptibly constant, and whose paths can therefore be determined from a single point on the earth or from the bridge of a steamer,[1] when Prince Albert of Monaco, accompanied by Hergesell, undertook two expeditions with his yacht (*Princess Alice*) to carry out such ascensions.

These experiments were carried on in 1904 in the triangle Oporto-Teneriffe-Azores and in 1905 along the route Gibraltar-Sargasso Sea (26° N. lat., 43° W. long.)-Azores (**15**). These are the results of the first expedition. In the lowest stratum there prevails the northeast trade wind with a mean velocity of 7 m/s. There is an adiabatic decrease in temperature and a relative humidity increasing from 70–80 per cent to 95 per cent, or often 100 per cent. In this case cumulus clouds form at the upper limit, which lies at a height varying between 100 meters and 600 meters. Then the temperature suddenly rises several degrees and the humidity falls to only 20–10 per cent. In this inversion stratum with a thickness of about 1,000 meters the wind is very irregular and light from the northeast,[2] shifting ordinarily with elevation, from northeast through north toward northwest, but twice (observed) shifting from northeast toward southeast and south. Above the inversion stratum there is found again a stratum with a gradient exactly adiabatic. The relative humidity increases with elevation so that the vapor content (richesse hygrometrique) is constant, which permits the inference of a descending current. In this stratum, which extends beyond 4,500 meters, the greatest height reached on this expedition there prevails a wind from the northwest. A counter-trade wind from the southwest was observed but once.

As an example, Hergesell gives the typical results of August 9, 1904 obtained, to the west of the Canary Islands.

TABLE 29.

Height.	Temperature.	Relative humidity	Direction of the wind.
Meters.	°		
0	+23.0	80	N. 52° E.
200	20.5	88	
400	18.5	88	N. 36° E.
500	18.0	93	
600	18.9	80	
800	24.5	35	
1,000	26.4	16	N. 29° E.
1,200	26.2	16	N. 15° E.
2,000	18.0	21	
3,000	9.0	30	
4,000	1.5?	40	
4,500	5.6	47	N. 25°W.

These results were fully verified during the expedition in 1905. Hergesell gives the following summary of observations on the directions of the winds:

August	Lat. N.	Long. W.	Winds in successive strata.
1	31° 10′	19° 30′	0–3,420 meters NE., 5,000 NW., 6,740 NE., 7,370 N. and at 10,000 NNW.
2	29° 17′	21° 50′	0–3,540 meters NE., 5,450 NW.–WNW., 9,420 NE., 10,200 E., 13,240 ENE.–NE., above SE.
7	25° 58′	35° 7′	0–1,800 meters NE., 2,100 SSE., 5,000 SW., 6,000 SE., 6,600 SSE., 8,400 SW., 9,000 WNW., 12,000 SW., 16,000 SE.
8	20° 41′	36° 36′	0–2,110 NE., 12,000 NW.–WNW.
9	27° 42′	38° 34′	0–5,600 NE.–NNE., 9,000 NW.–NNW.
11	30° 4′	42° 30′	0–4,140 NNE., 4,240 N., 8,400 NNE.
16	31° 44′	42° 39′	0–4,540 ENE.
23	37° 3′	27° 21′	0–2,210 NE., 2,800 NW., 3,280 NE., 3,840 N., 12,330 NNW.–NW.

[1] We will not treat here the experimental methods employed in these researches—methods well known at present.

[2] In general, as at Trappes, Hald, etc., the study of HIGHS shows that, in general, there is a zone of light winds at a certain height, a zone through which kites ordinarily can not rise. They form a horizontal line called "la ligne de canards." See also the irregular march of intermediate clouds over the Antilles (Fig. 5) and C. J. P. Cave, The structure of the atmosphere in clear weather, Cambridge, 1912.

The velocity of the trade wind was ordinarily 5 to 6 m/s, that of the upper wind 10 to 15 m/s.

Once, at the most southern station, the upper wind blew from southwest-southeast; everywhere else from northwest. Hence the counter-trade from southwest was found only once.

The expeditions of the *Otaria* fitted out by Teisserenc de Bort and Rotch were more important. The first expedition began July 1, 1905, and the *Otaria* visited in turn Madeira, the Canaries, Cape Verde Islands, the Canaries, and the Azores. The observations consisted, at sea, in flights of kites and pilot balloons; with the exception of those of August 13 the latter were sent from the land in order to have a base which would permit of an exact determination of the path.

The following expedition was made in the month of February, 1906. It was of short duration, its principal purpose being to determine whether the flights made on the open sea gave the same superposition of currents as those made at Teneriffe. The balloons sent up in February demonstrated the existence of the counter-trade wind above the trade in the regions of the Canary Islands. It remained to study the intertropical circulation itself and to pursue soundings in the central portion of the Atlantic.

The third expedition visited in turn Madeira, the Cape Verde Islands, Sierra Leone, Ascension Island, the Cape Verde Islands, Teneriffe, the Azores and then returned to Europe after having sailed a great quadrilateral to the west of the Azores as far as 47° of longitude west of Paris. Leaving Marseilles at the close of April the expedition returned to Havre on October 18.

On this expedition there were made 24 flights of pilot balloons and 46 flights of kites. In calm weather captive balloons carrying self-registering instruments were also often employed, which were in this manner sent to about 5,000 meters, as far as the counter-trade wind.

Then Teisserenc de Bort alone outfitted still another expedition which left Havre on July 1, 1907, for the Azores, where began the first flights of balloons, which were continued chiefly to the southwest of the Cape Verde Islands, which during two periods of 13 to 14 days each permitted the following of the daily circulation at different heights above these parts. Several balloons reached the isothermal stratum in a manner not to be questioned. The ascents were 41 in number, of which 29 were sounding balloons, and of these 20 were recovered giving good curves; the others served as pilot balloons. We give here some typical specimens of the numerous observations. (Tables II–V omitted.)

The general results concerning the circulation of the air are thus summarized by Teisserenc de Bort:

"The wind system is rather regular in a given region and the whole of the circulation over the part explored (35° N. to 8° S. lat., from the coasts of Europe to 47° of longitude west of Paris) can be summarized as follows:

"The regular trade wind from north to northeast, which blows at the level of the sea, forms a stratum whose mean thickness is hardly 1,000 meters, then comes a wind zone still having a north component which blows ordinarily from the northwest. These winds from the northwest appear to cease at 10° from the point of convergence of the trade wind, which in summer is found toward 8° north latitude, consequently to the south of the Cape Verde Islands. Above, at an elevation begins the region of winds with south component which form the counter-trade. The latter are met with at a lesser altitude as the Equator is approached; thus toward the Cape Verde Islands the counter-trade is found in the neighborhood of 1,800 meters and at the latitude of the Canary Islands it blows above 3,000 meters, which corresponds besides to the observations made on the Peak of Teneriffe.[1]

"The equatorial region, that is to say that where lies the point of meeting of the trade winds and whose latitude varies slightly in the course of the year, is occupied by winds with east component very predominant up to the greatest heights that have been explored. From the fifth degree of south latitude there is found above the trade winds proper, winds with north component, which form the counter-trade; these winds are from northeast and sometimes from northwest. These changes in direction can be explained in that these different superposed layers come from different regions of barometric minimum.

"The counterpart of the northwest winds which are met with in the northern hemisphere above the northeast trade wind is given us by the streams of wind from the southwest which are found in the vicinity of Ascension Island above the southeast winds, properly called trade winds of the southern hemisphere. These winds are superposed upon the streams of the trade or counter-trade wind.

"These complications of the strata of different winds are also met with in the northern hemisphere. Examples are found in the paths of balloons determined by sightings made at Trappes during a 10-year period when these flights were made in high pressures.

"In summarizing we can say that the intertropical circulation is indeed in its chief characteristics such as has hitherto been supposed.

"The counter-trade wind in its entirety predominates over great areas, moving from southeast, then from south, from southwest, and finally terminating in a west wind at the latitude of the Azores. Naturally, there are some daily irregularities, and the case is met with where the trade wind extends up to 7 to 8 kilometers and even farther[2] and where the counter-trade seems to be wanting; but these conditions are of short duration or limited to one portion of the north Atlantic high pressure area, as is seen when the observations are extended over several months of three different years, which permits the determination of the normal system."

Thus the conclusion of Hergesell that the maximum of the North Atlantic is fed from the north by a northwest wind is confirmed. But, thanks to the extension of researches to greater heights, to more southern latitudes, and during several years, all the system of winds developed from cloud observations has been established.

As for the regions of the Antilles, we have seen from the observations of clouds by Bigelow that at the height of the cirro-cumulus or cirro-stratus (7 to 8 kilometers), the counter-trade wind blows from west or west-southwest, exactly opposite to the direction of the trade wind, which blows there from east to east-northeast, and that there is between these currents, at the height of the middle clouds, a stratum with variable winds.

In December, 1909, Hergesell carried on in the region of the Antilles some flights from the *Victoria Louise* of the German Navy. Emperor William paid all of the expenses of the expedition, which embarked on the *Victoria Louise* in the port of St. Thomas, the results of which are given in Table VI.

[1] However, one sees from the tables that this height is very variable.

[2] Once, July 8, 1906, near Teneriffe a NNE. wind was observed to a height of 11,050 meters.

TABLE VI.

Dec. 6, 1909. 15° 11′ N., 66° 58′ W. Gr.	Dec. 7, 1909. 15° 41′ N., 66° 57′ W. Gr.	Dec. 8, 1909. 14° 27′ N., 68° 40′ W. Gr.	Dec. 9, 1909. 15° 10′ N., 67° 31′ W. Gr.
Meters. °	*Meters.* °	*Meters.* °	*Meters.* °
1,160.....E 39 N.	1,450.....E. 25 N.	1,160.....E. 12 N.	2,570.....E. 33 N.
2,610.....E. 82 N.	2,610.....E. 30 N.	2,900.....E. 35 N.	4,400.....E. 64 S.
4,060..... E.	4,920.....E. 13 N.	5,510.....E. 7 S.	4,910.....Calm.
5,510.....E. 7 S.	5,510.....E.85 N.	6,380.....E. 4 N.	6,740..... E.
6,960.....W. 78 N.	6,090.....E. 42 N.	8,410.....E. 6 S.	8,710.....W. 60 S.
8,410.....W. 40 N.	6,670.....E. 7 S.	8,700.....Calm.	10,920.....W. 28 S.
8,990.....W. 15 S.	7,830.....E. 35 N.	9,280.....W 13 S.	11,470.....W. 15 N.
9,570.....W. 20 N.	8,120.....E. 45 S.	10,730..... W.	12,900..... W.
10,150.....W. 7 S.	10,730.....W. 7 N.	12,470.....W. 24 S.	15,000.....W. 40 S.
11,310.....W. 13 S.	11,310.....W. 25 S.	13,630.....W. 37 S.	16,800.....E. 83 S.
12,760.....W. 27 S.	12,470.....W. 29 S.	14,790.....W. 21 S.	
13,630.....W. 68 S.	14,210.....W. 21 S.	15,370.....W. 19 N.	
		16,240.....W. 26 S.	
		16,530.....E. 47 S.	

Dec. 10, 1909. 15°45′ N. 67° 21′ W. Gr.	Dec. 21, 1909, Noon. 17° 56′ N. 75° 58′ W. Gr.	Dec. 21, 1909, p. m. 18° 8′ N. 75° 30′ W. Gr.	Mean curve of the flights Dec. 6-10.
Meters.	*Meters.*	*Meters.*	*Meters.*
2,040.....E. 5 N.	1,080..... E.	1,000..... E.	1,005.....E. 22 N.
3,760.....E. 25 N.	2,130.....E. 30 N.	1,910.....E. 20 N.	2,955.....E. 31 N.
7,020.....E. 55 S.	2,650.....E. 84 N.	3,040.....W. 68 N.	4,355.....E. 6 N.
8,580.....Variable.	3,400.....W. 30 S.	3,720.....W. 40 S.	5,785..... E.
10,470.....W. 30 N.	5,410.....W. 72 S.	4,200.....E. 79 S.	7,145.....E. 15 N.
11,120.....W. 24 N.	6,410.....W. 22 N.	5,960.....W. 82 S.	8,340.....W. 6 N.
13,960.....W. 15 S.	7,190.....W. 4 S.	6,730.....W. 12 N.	10,285.....W. 3. N.
14,570.....Variable.	8,520.....W. 11 N.	7,520.....W. 23 N.	11,600.....W. 15 S.
15,180.....W. 10 S.	9,840.....W. 23 S.	8,580.....W. 22 N.	13,540.....W. 23 S.
15,500.....W. 60 S.	10,010.....W. 20 S.	9,900.....W. 16 S.	14,100.....W. 45 S.
	11,440.....W. 25 S.	11,950.....W. 20 S.	
	11,970.....W. 18 S.	12,560.....W. 15 S.	

As is seen, the trade wind blows from the east up to the height of about 7,000 meters. Moreover the velocity of the wind was rather high, 9 m/s, up to 3,000 meters, but light and variable between 3,000 and 7,000 meters. Above began the counter-trade wind from the west, which above 10,000 meters shifted gradually to southwest. Its velocity was on an average 2 m/s.

In order to verify these results Jonas was sent in the following year to make "check" observations with pilot balloons. He arrived with the *Freya* of the German navy at Curaçao (Dec. 1), where he remained until the 9th, then pursued his observation at Port of Spain (Trinidad) from the 11th to 18th, and on the open sea around Trinidad from the 19th to the 23d.

The results [obtained] by Hergesell were fully verified. Up to 4,000 meters the wind from the region of east south-east remained constant and rather strong. From 4,000 to 8,000 meters the winds were light and variable and above that they moved from northwest or southwest.

Hence the results derived from the cloud observations cited above are entirely in agreement with those found by Hergesell and Jonas.

3. *Southern Hemisphere.*

The officers of several merchant steamers of the Hamburg-South American lines in 1906–1908 sent up pilot balloons along their courses according to instructions from the great institution of the German marine, the Deutsche Seewarte. The results of 65 flights are published by Koppen.(**16**) These experiments were continued for three years, 1909–1911, by H. Meyer, instructor in navigation of the school of the Norddeutsche Loyd Co., during long voyages on the Atlantic and on the Pacific.(**17**) Table VII gives the observations made during 16 flights at a rather great height south o latitude 7° N.

TABLE VII.—*The Southern Hemisphere.*

1. Apr. 24, 1906. 7° N. 29½° W. Gr.	2. Oct. 31, 1907. 4° 23′ N. 29° 52′ W.	3. Sept. 25, 1907. 1° 18′ N. 30° 51′ W.	4. Jan. 6, 1910. 0.2° N. 29.3° W.
Meters. °	*Meters.* °	*Meters.* °	*Meters.* °
0..... NE.	0..... SSE.	0..... SE.	0..... ESE.
500.....N. 57 E.	500.....S. 42 E.	500.....S. 42 E.	500.....S. 52 E.
1,000.....N. 71 E.	1,000.....S. 36 E.	1,000.....S. 64 E.	1,000.....S. 61 E.
1,500.....S. 69 E.	1,500.....S. 76 E.	1,500.....N. 35 E.	1,500.....S. 70 E.
2,000.....S. 60 E.	2,000.....N. 46 E.	2,000.....S. 25 E.	2,000.....S. 82 E.
2,500.....S. 66 E.	2,500.....N. 65 E.	2,500.....S. 38 E.	2,500.....N. 75 E.
3,000.....S. 77 E.		3,000.....S. 30 E.	3,000.....N. 70 E.
			3,500.....N. 58 E.
			4,000.....N. 65 E.
			4,500.....S. 70 E.
			5,500.....S. 50 E.

5. Mar. 6, 1907. 1° S. 32° W.	6. Jan. 4, 1910. 5.2° S. 30° W.	7. Jan. 5, 1910. 2.1° S. 29.6° W.	8. Jan. 6 1908. 26° 22′ S. 44°26′ W.
Meters. °	*Meters.* °	*Meters.* °	*Meters.* °
0..... SSE.	0.....SSE.	0.....E.	0.....SSE.
500.....S. 77 E.	500.....S. 62 E.	500.....N. 73 E.	500.....S. 85 E.
1,000.....S. 75 E.	1,000.....S. 76 E.	1,000.....N. 42 E.	1,000.....N. 85 E.
1,500.....S. 76 E.	1,500.....S. 85 E.	1,500.....N. 17 E.	1,500.....S. 15 W.
2,000.....S. 75 E.	2,000..... E.	2,000.....N. 47 E.	2,000.....N. 80 W.
2,500.....S. 75 E.	2,500.....N. 88 E.	2,500.....N. 35 E.	2,500.....S. 53 W.
3,000.....S. 75 E.	3,000.....N. 75 E.	3,000.....N. 35 E.	3,000.....N. 70 W.
	3,500.....N. 50 E.	3,500.....N. 35 E.	4,000.....N. 62 W.
	4,000.....N. 65 E.	4,000.....N. 35 E.	5,000.....N. 54 W.

9. Oct. 22, 1910. 15.3° S. 91.1° W.	10. Déc. 1, 1910. 31° S. 161° E.	11. Oct. 30, 1910. 21.4° S. 114.1° W.	12. Nov. 3, 1910. 26° S. 130.4° W.
Meters. °	*Meters.* °	*Meters.* °	*Meters.* °
0.....SSE.	0..... ESE.	0.....ENE.	0..... SW.
500.....S. 85 E.	1,000.....N. 25 E.	1,000.....N. 82 E.	500.....S. 62 W.
1,000.....S. 82 E.	2,000.....N. 25 E.	2,000.....S. 70 E.	1,000.....S. 82 W.
1,500.....S. 82 E.	3,000.....N. 74 E.	3,000.....S. 28 E.	1,500.....N. 82 W.
2,000..... E.	4,000.....N. 84 E.	4,000.....S. 15 E.	2,000.....N. 48 W.
2,500..... S.	5,000.....S. 85 E.	5,000.....N. 80 W.	2,500.....N. 65 W.
3,000.....S 15 W.	6,000.....S. 63 W.	6,000.....N. 75 W.	3,000.....N. 62 W.
3,500.....S. 35 W.	7,000.....S. 87 W.	7,000..... W.	
4,000.....N. 85 W.	9,000..... W.	8,000.....N. 85 W.	
4,500..... W.	10,000.....N. 88 W.		
5,000.....S. 75 W.	11,000.....S. 72 W.		
6,000.....S. 25 W.	12,000.....S. 80 W.		
7,000.....N. 40 W.			
8,000.....N. 40 W.			
9,000.....N. 30 W.			

13. Nov. 16, 1910. 25.3° S. 158.1° W.	14. Nov. 17, 1910. 25.8° S. 161° W.	15. Nov. 20, 1910. 26.2° S. 170.6° W.	16. Oct. 25, 1910. 17° S. 98.2° W.
Meters. °	*Meters.* °	*Meters.* °	*Meters.* °
0..... SE.	0..... ESE.	0..... E.	0..... ESE.
1,000.....S. 50 E.	1,000.....S. 68 E.	1,000.....S. 87 E.	1,000.....S. 60 E.
1,500.....N. 42 E.	2,000..... S.	1,500.....N. 72 E.	2,000.....S. 50 E.
2,000.....N. 12 E.	3,000..... W.	3,000..... S.	3,000.....S. 36 E.
3,000.....N. 84 W.	4,000.....Calm.	4,000.....S. 45 W.	4,000.....S. 38 E.
4,000.....N. 84 W.	5,600..... W.	5,000.....S. 50 W.	5,000.....S. 48 E.
5,000.....N. 84 W.	6,000.....N. 66 W.	5,500.....S. 50 W.	6,000.....S. 26 E.
6,000.....N. 15 E.	7,000.....S. 38 W.		7,000.....S. 23 E.
7,000..... E.	8,000..... S.		8,000.....S. 12 E.
8,000..... E.	8,500.....S. 13 E.		8,500.....S. 20 E.

4. *Batavia and Samoa.*

Some observations have been made by means of sounding or pilot balloons at Batavia, 6° south latitude, and at Samoa, 14° south latitude.

The observations at Batavia from September 16, 1911, to July 5, 1912, are published in the Publications of the Commission on Scientific Aeronautics, 1911–12.

The station is in the northwest monsoon system and that of the southeast trade wind, but, as we have seen, the monsoons are limited to a relatively low layer of the atmosphere. Also it is seen from Table VIII [omitted] that above 100–500 meters there prevail winds from the east, as would be presupposed, Batavia being in the equatorial zone. However, on May 2 a southwest wind prevailed as far as 4,000 meters, where the observations ended. On April 11 there were observed variable winds

between northwest and southwest above 12,000 meters, that is, in the stratosphere. This anomaly presented itself also at 5,000–6,000 meters on June 6. Otherwise, east winds blew at the greatest heights reached.

From 40 years of hourly observations the winds of each month are on an average as follows (**18**):

January	N. 48° W.	July	N. 53° E.
February	N. 42° W.	August	N. 46° E.
March	N. 29° W.	September	N. 34° E.
April	N. 31° E.	October	N. 32° E.
May	N. 50° E.	November	N. 1° W.
June	N. 56° E.	December	N. 54 W.

Nos. 1 to 6 of Table VII show the easterly current of the tropical zone. No. 7 presents the upper winds from the northeast corresponding to the southeast winds of the Cape Verde Islands. Nos. 8 to 16 contain observations made between South America and Australia in the middle of the trade wind. Under Nos. 8, 9, 11, and 14 are seen the trade wind from southeast and the counter-trade from northwest. No. 15 with upper winds from the southwest corresponds to the upper winds from the northwest in the neighborhood of the Azores. In two cases, Nos. 13 and 14, there are found unusual winds from south to east above 7,000 meters. In No. 10, the polar limit of the trade wind, there are met with above 6,000 meters the west winds of the Temperate Zone as at the northern limit of the trade wind in the north Atlantic. Nos. 12 and 16 show some irregular cases like those we have encountered north of the Equator. No. 12 is an instance in which the southeast trade wind blows from southwest with the regular counter-trade from northwest. We have seen that Teisserenc de Bort once found at the latitude of Teneriffe the northeast trade wind blowing as far as the greatest height reached. No. 16 gives an analogous example for the southeast trade at 17° south latitude on the Pacific Ocean.

From these findings Perlewitz correctly concluded that there is perfect symmetry between the directions of the winds over the North Atlantic and those over the South Atlantic and of the Pacific south of the Equator.

In winter the northwest monsoon is plainly evident, but in summer the southeast trade winds become northeast through local causes, Batavia being situated on the north coast of Java.

We have also some observations from Samoa (14° S. lat.) (**19**) for the years 1909 and 1910. However, the situation of this island is very exceptional; it could be said that it lies in the Southern Hemisphere in winter and almost in the Northern Hemisphere in summer. In fact the thermal equator, which generally lies north of the Equator removes in summer in this part of the Pacific to the south of 14° south latitude. Then Samoa is situated nearly on the thermal equator, sometimes a little to the north of it, sometimes a little to the south; the winds with east component are, as must be expected, prevalent at all heights. In winter (May–August) the place lies on the contrary most often under the southeast trade winds, and the upper winds have a west component. But the winds at the surface of the earth are often irregular because of land and sea breezes, which are strongly developed.

But the upper currents determined by the course of the cirrus clouds are also irregular. They have most often a very decided west component. These are observations from that place:

Seasons of the Southern Hemisphere.

	N.	NW.	W.	SW.	S.	SE.	E.	NE.
Summer	0	1	4	2	1	2	1	0
Winter	0	2	5	1	3	1	0	0

The observations made by the use of kites and pilot balloons rarely extend beyond 3,000 meters. We give here some examples.

Dec. 1, 1910.	Jan. 10, 1910.	Feb. 18, 1910.	Jan. 20, 1909.	May 29, 1909.
Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
0– 400.....NE.	0..E.	0..E.	0...NW.	0..E.
400–1,200.....N.	500..E.	500..ESE.	500...NW.	500..E.
1,200–2,000.....NNW.	1,000..E.	1,000..E.	1,000...NW.	1,000..E.
2,000–3,000.....NW.	1,500..E.	1,125..E.	1,500...NW.	1,170..E.
3,000–3,480.....E.	1,780..E.	.....	2,500...NW.	.....
Above—CiSt.W.	CiSt...ESE.	Ci.....SE.	Orage.	CiSt..WNW.

May 19, 1910.	June 2, 1909.	July 7, 1910.	Aug. 4, 1910.	Oct. 18, 1910.
Meters.	*Meters.*	*Meters.*	*Meters.*	*Meters.*
0– 100...S.	0.E.	0.E.	0– 300.Calme.	0– 200..ENE.
100– 200...Calme.	500.E.	500.E.	300– 600.SSE.	200–1,200..E.
220–1,870...ENE.	1,000.E.	1,000.E.	600–2,500.W.–SW.	1,200–1,400..ENE.
1,870–2,750...NW.	1,500.E.	1,500.E.	2,500–2,900.Calme.	1,400–2,800..NE.
2,750–7,100...NNW.	1,800.E.	2,000.S?	2,900–5,200.SSW.–SE.	2,800–4,100..NNE.
Above—CiCu.W.	Ci..... WNW.	.....	Ci.....SSW.	.....

We see that the wind system of Samoa is not one representative of the air currents of the Tropics. The winds are very changeable from day to day in every month and at every elevation. This depends on the situation of this island between three wind systems—the southeast trade wind, the tropical calm belt, and the monsoons of Australia, New Guinea, and the rather large islands to the west. Because of this the gradients in temperature and pressure of the air are very irregular, wherefore there often arises a wind from the west instead of the east in the upper regions. It [is not our purpose] to discuss here in detail these local anomalies, which do not influence the general movements of the atmosphere.

5. *Simultaneous observations in Greenland and Iceland.*

We have seen that the course of the cirrus clouds in Greenland and Iceland is on the average from the east instead of from the west as would be expected. Some experiments made by Hergesell with sounding balloons on the sea in these regions have confirmed these observations. In order to study this anomaly more closely, De Quervain of Zurich and Thorkelsen of the Danish Meteorological Institute made simultaneous observations; De Quervain on the west coast of Greenland, between 64° 11′ and 68° 51′ north latitude, and Thorkelsen at Akureyri on the northern coast of Iceland, from the close of April to the beginning of July in 1909. These most complete observations are found in Table IX (Godthaab 64° 11′ N., Agto 67° 56′ N., Godhavn 68° 51′ N.).

TABLE IX.

Altitude.	Godthaab —Apr. 27.	Akureyri —Apr. 28.	Godthaab —Apr. 29.	Godthaab —May 7.	Akureyri —May 7.	Godthaab —May 12.
Meters.						
0– 100	N. 30° E.	S. 82° W.	N.	E. 30° N.	S. 19° E.	N. 36° E.
500– 1,000	N. 20° E.	N. 27° W.	N. 24° E.	E.	S. 11° E.	N. 42° E.
1,000– 1,500	N. 20° E.	N. 16° E.	N. 24° E.	S. 30° E.	S. 9° E.	N. 28° E.
2,000– 2,500	E. 20° N.	N. 33° E.	N. 44° E.	S. 34° E.	S. 51° W.	N. 36° E.
3,000– 3,500	S. 33° E.	N. 16° E.	N. 29° E.	S. 15° E.	S. 60° W.	E. 7° N.
4,000– 4,500	E. 25° S.	N. 15° E.	E.	S. 4° E.	S. 55° W.	E. 20° E.
5,000– 5,500	E. 26° S.	.....	E. 18° S.	S. 3° E.	S. 57° W.	S. 20° E.
6,000– 6,500	E. 28° S.	.....	E. 37° S.	S. 13° W.	S. 44° W.	S. 18° E.
7,000– 7,500	E. 29° S.	.....	E. 42° S.	S. 9° W.	S. 37° W.	S. 21° E.
8,000– 8,500	.....	.....	E. 45° S.	S. 5° W.	S. 48° W.	E. 11° S.
9,000– 9,500	.....	.....	S. 25° E.	.....	S. 45° W.	N. 38° E.
11,000–11,500	.....	.....	E. 39° N.	.....	S. 59° W.	E. 30° S.
13,000–13,500	.....	.....	E. 41° N.	.....	.....	.....
14,500–15,000	.....	.....	E. 10° N.	.....	.....	.....

Altitude.	Akureyri —May 12.	Agto —May 29.	Akureyri —May 29.	Godthaab —June 21.	Akureyri —June 21.	Akureyri —June 22 (soir).
Meters.						
0– 100	S. 26° E.	S. 25° W.	N. 24° W.	S. 43° W.	S. 54° E.	N. 35° W.
500–1,000	S. 29° W.	W. 35° S.	S. 18° W.	E. 17° N.	S. 47° E.	N. 5° S.
1,000–1,500	N. 62° W.	W. 41° S.	S. 42° W.	E. 15° S.	N. 64° E.	N. 68° W.
2,000–2,500	N. 51° W.	S. 30° W.	S. 30° W.	S. 23° W.	N. 36° E.	N. 45° W.
3,000–3,500	N. 36° W.	W. 29° S.	S. 35° W.	W. 34° S.	N. 43° E.	N. 22° W.
4,000–4,500	N. 30° W.	W. 2° S.	S. 23° W.	S. 44° W.	N. 40° E.	N. 31° W.
5,000–5,500	N. 28° W.	W. 28° N.	S. 17° W.	W. 45° S.	N. 36° E.	N. 40° W.
6,000–6,500	N. 30° W.	W. 27° N.	S. 25° W.	S. 37° W.	N. 32° E.	N. 25° W.
7,000–7,500	N. 28° W.	.....	.....	S. 38° W.	N. 30° E.	N. 22° W.
8,000–8,500	N. 31° W.	.....	.....	W. 39° S.	N. 26° E.	N. 16° W.
9,000–9,500	.....	.....	.....	W. 41° S.	N. 29° E.	N. 17° W.

It is seen that at Akureyri winds from the east often prevail in the lower strata, but that there are superposed winds from west to northwest in the upper strata. This is the usual system of winds to the north of a minimum [of pressure] and which is ordinarily open above. The great minima thus pass generally to the south and east of Iceland.

Over the waters of Baffin Bay almost always open and bounded on the east by Greenland always covered with ice and on the west by Ellesmere Land also very frigid there exists almost constantly an almost stationary depression[1] changing more or less in depth. Over Greenland there extends, on the other hand, a tongue of high pressure from the Arctic Ocean. But, as we have seen above, a depression having a high pressure area to the north is closed even above. This explains how the winds are predominantly from the east at all elevations, with few exceptions, in May and June.

We have seen [Table I omitted] that in Ellesmere Land, situated to the northwest of Baffin Bay, the prevailing winds are from the north from the ground as far as into the region of the cirrus clouds. Only in summer are winds from the south prevalent. Hence Ellesmere Land is situated in the rear portion of the constant depression over Baffin Bay. This depression resembles the continuous whirls which form in an inlet cut in the bank of a river. Here the river is the great current from the west prevailing over all of the temperate zone and which we have found in the high regions, even in the polar regions, Jan Mayen, Kiruna, Spitzbergen, Franz Josef Land, etc.

IV.

CONFIRMATION OF THE PRECEDING FINDINGS BY VOLCANIC PHENOMENA.

On the 29th and 30th of March, 1875, a very heavy rain of ashes fell in Scandinavia. The ashes came from the volcano Askja, situated in the eastern part of Iceland (65° 2′ N. lat., 16° 40′ W. long.), whose height is about 1,000 meters. There was a very violent eruption on the morning of March 29. The ashes fell at 7 a. m. on the eastern coast of Iceland between Seidisfjord on the north and Berufjord on the south. At 8 p. m. they fell on the western coast of Norway between Brono on the north and Samnanger near Bergen on the south. Consequently they had crossed the sea with a velocity of 23.8 m/s. At Stockholm the ashes began to fall at 11 a. m. of the following day. On the coast of the Baltic Sea they fell between Sollefteå on the north and Södertelje on the south. Consequently while crossing Sweden the wind had a velocity of 14.1 m/s. On the other coast of the Baltic Sea there were no observations of ashes.

At this time the ashes were carried by the winds of the lower or middle strata of the atmosphere. By the eruption of the volcano Katmai in the Aleutian Islands on June 6–8, 1912, the volcanic products were, on the contrary, thrown into the highest regions of the atmosphere. The finest dust remained there for two to three months after having been carried very rapidly in turn over North America, the Atlantic, and Europe in the form of a fan as far to the east as Siberia. All summer the sky had a grayish color, through this veil the sun appeared like a disk of polished copper. This phenomenon was observed toward the south as far as Bassour in southern Algeria, where it seriously interfered with the work of an actinometric expedition of the astrophysical observatory of the Smithsonian Institute, under the direction of Dr. C. G. Abbot, and A. Ångström, of the University of Upsala. In September, when the phenomenon had almost disappeared in Europe, there were observed, according to a letter from Nakamura, in Japan, red twilights like those observed after the celebrated eruption of Krakatoa.

This eruption of Krakatoa on August 23, 1883, is the most terrible in historic times. The volcano is situated on an island in the strait between Sumatra and Java, near the equator. At 10 a. m. a terrific explosion hurled a great part of the island into the air to a height probably greater than that of the atmosphere. An enormous mass of the finest dust remained suspended in the highest regions, and caused red twilights, which continued for several months. These red twilights made the circle of the earth between the Tropics in 12 days, that is with a velocity of 34.5 m/s. This is the first time that constant equatorial wind from the east around the world was proven.

Along the meridians this phenomenon traveled, on the contrary, very slowly. It arrived at North Cape and at southern Greenland only toward the end of November and at Buenos Aires and Valparaiso at the beginning of October.

These examples, which could be supplemented, prove the existence of a current from west to east in the temperate zone and one from east to west at the Equator.

GENERAL CONCLUSIONS.*

From what precedes there must necessarily be drawn the following conclusions, found without any preconceived theory, and directly from observations made by different methods:

1. About the thermal equator there is a great current from east to west. At the surface of the earth it is generally light (equatorial calms), but very constant and strong in the upper strata of the atmosphere (34 m/s).

2. In the temperate zones there prevail currents from west to east.

[1] Only once, May 5, a depression passed from Baffin Bay to the east over Greenland.

*There is a Review by J. S. Dines in *Nature*, (London) Jan. 2, 1919, pp. 348–349, and Sci. Am. Suppl., Apr. 4, 1919, p. 217.

3. In the upper regions these currents are deviated to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. Thus the equatorial current from the east becomes a current successively from southeast, south, southwest, and west, the counter-trade of the Northern Hemisphere, and successively a current from northeast, north, northwest, and west, the counter-trade of the Southern Hemisphere. These upper currents feed the tropical high pressure regions from the equatorial side. In the same manner the westerly currents of the temperate zones become above northwest and southwest, respectively, and feed the tropical maxima from the polar sides.

4. From these maxima there blow in the lower strata the trade winds from northeast and southeast toward the equator, from directions opposite to the southwest to west winds in the Northern Hemisphere and the northwest to west winds of the Southern Hemisphere.

5. From the polar regions observations are still not very numerous; from those cited above it is seen, however, that winds from the east are frequent at the surface of the earth above latitude 60° to 70°, but that generally winds from northwest to southwest blow above in the upper strata. This is probably explained by the frequent passage of barometric depressions which are not closed above on their polar sides. If, however, there exists a maximum to the north, winds from the east blow above also. Over Baffin Bay, whose waters are more or less open and surrounded by very cold countries, there exists, especially in winter, an almost stationary depression with winds from southeast to east in Greenland and from the north in Ellesmere Land.

6. The greater the elevation, the more constant from the west are the winds of the temperate zones, from which it is to be concluded that cyclones and anticyclones are phenomena that originate in the lower strata of the atmosphere.

7. Hence a direct upper current from the Equator to the poles does not exist, nor a lower current in the opposite direction from the poles to the Equator.

8. However, there is a slow exchange of air along the meridians, caused by continuous cyclonic and anticyclonic whirls in the temperate zones. Indeed each of these whirls carries air on the one side from south to north and on the other from north to south. Besides, as the air has an ascending movement in the cyclones and a descending one in the anticyclones, it is seen that the masses of air from different latitudes become gradually mixed.

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GENERAL CIRCULATION OF THE ATMOSPHERE.

By L. GANGOITI, S. J.

Translation and abstract of 8 folio pages from the report of 1917 of the Meteorological Observatory of Belen College, Habana.

The author discusses the theory of the trades and antitrades and presents data, principally observations of the direction and movement of high clouds to refute the existence of the anti-trades as set out by Dove and other modern writers.

He refers to observations made at Quito, latitude 0° 13′ south, in June, 1877, of volcanic smoke which rose to an altitude of 8,000 or 9,000 meters and was then carried in a westerly direction by an easterly current. Also he discusses 12 observations of the movement of smoke from Cotopaxi made in Ecuador in the immediate vicinity of the Equator in 1907 and 1908, which show directions as follows: Northwest 1, west or southwest 3, east 4, and southeast 4.

Volcanic ashes from the eruption of Coseguina (Nicaragua) in 1835 fell in Mexico to the northwestward, in Bogota to the southeastward, and in Jamaica to the northeastward, from which he draws the conclusion that there must have been high currents from different directions, i. e., that the southwest anti-trades were not continuous. Observations of smoke from Colima, latitude 19° 30′ 25″N., altitude 3960.9 meters, during 13 months scattered through a period of three years, show that during the period April to September the most frequent quadrant is the northwest; during November, December, and January, the southeast; in February, the southeast and southwest equally; while in March it is the southwest, the latter being the only month that shows a prevalence of the high currents having a direction the same as that attributed to the anti-trades.

Cirrus cloud observations made in Ecuador during 38 months in 1907, 1908, 1909, and 1910 show that by far the most frequent direction is the northeast (29 months), and next the northwest (7 months), while in two other months the number of observations of northeast and northwest currents was equal.

Cloud observations at Port of Spain, Trinidad, latitude 10° 35′ N., show that the cirrus move from the west from

November to May, and from the east from June to October, while the cirro-stratus come from the east during the period June to November and from the west during the remainder of the year. At Willemstadt, Curaçao, latitude 12° 10′ N., the cirrus move from the east in July and August. At Kingston, Jamaica, latitude 17° 58′ N., the direction is north-northeast in July and August and north in September. At San Juan, Porto Rico, latitude 18° 29′ N., three entire years of observations show southeast 18 months and east 12 months, with no indications of a seasonal variation. At Habana, latitude 23° 8′ 14″ N., for the period 1892–1902, the cloud movement is as follows:

	Cirrus.	Cirro-stratus.
January	S. 81° W.	S. 79° W.
February	S. 83° W.	S. 80° W.
March	N. 88° W.	S. 89° W.
April	N. 89° W.	S. 89° W.
May	N. 83° W.	S. 84° W.
June	N. 49° W.	N. 84° W.
July	N. 28° E.	N. 52° E.
August	N. 48° E.	N. 54° E.
September	N. 27° E.	N. 89° E.
October	N. 87° W.	S. 81° W.
November	S. 77° W.	S. 72° W.
December	S. 80° W.	S. 73° W.

From this table it will be seen that the cirrus move from the first quadrant during July, August, and September, from the third quadrant in November, December, January, and February, and from the fourth quadrant in March, April, May, June, and October.

From the observations of the Antilles before referred to the author concludes that there is nothing that can give rise to the slightest suspicion of the existence of a high current which is constant, or nearly so, nor do they bear out the theory that the most elevated clouds move from the southwest toward the northeast between the equator and the tropics.

The writer next examines eight months of observations scattered over the years 1882 and 1883 of high clouds at Funchal (Madeira), latitude 32° 38′ N., which show most frequent directions as follows: North 4, north-northeast 1, northeast 1, northwest 2.

At Montpellier, France, latitude 43° 37′ N., 18 months of observations of cirrus and cirro-stratus clouds made during 1881 and 1882 show most frequent movement from various directions. Observations at Moncalieri, latitude 45° N., for the years 1878 and 1879 show a prevalence of high currents from the northeast and north in practically every month.

He also quotes extracts from the Indian Memoirs, Volume XV, as follows:

Madras: Latitude 13° 4′ for the period 1896–1900. Observations show that in February the prevailing direction is S. 18° E., in May, S. 69° E., and in June, S. 83° E. For the same station for a period of six years the following is given:

	Cirrus.	Cirro-stratus.
August	N. 89° E.	N. 66° E.
September	S. 84° E.	N. 48° E.
October	S. 57° E.	S. 79° E.
November	S. 35° E.	

Visagapatan, latitude 17° 42′ (1897–98):

	Cirrus.	Cirro-stratus.
August	NE.	N. 71° E.
September	S. 56° E.	N. 45° E.
October	S. 64° E.	S. 76° E.
November	S. 24° E.	S. 34° E.
December	S. 28° E.	S. 8° E.

Allahabad, latitude 25° 26′ (1897–1900):

	Cirrus.
July	N. 78° E.
August	N. 7° E.

The cirrus at Allahabad have exactly the same direction in December, January, and May, and the cirro-stratus in March, as these at Habana. In the other months, with the exception of July and September, the angular differences are unimportant.

At Manila, latitude 14° 34′ 42″, for the period 1890–1898, observations of high clouds give results as follows:

January	S. 6° 00′ E.	July	N. 76° 28′ E.
February	S. 11° 20′ E.	August	N. 83° 53′ E.
March	S. 17° 29′ E.	September	N. 62° 58′ E.
April	S. 82° 54′ W.	October	S. 47° 25′ E.
May	N. 73° 29′ E.	November	S. 68° 44′ E.
June	N. 75° 23′ E.	December	S. 55° 29′ E.

Those of the second [fourth?] quadrant predominate from October to March; those of the third quadrant in April, and those of the first quadrant from May to September. In July, August, and September the cirrus at Habana also predominate in the first quadrant.

An inspection of a number of Japanese stations shows that from June to September the movement of the cirrus for the most part is from a point between north and east.

In conclusion, the author states that the data presented indicate that there are variations in the direction of the high currents in the region of the cirrus and cirro-stratus, the fundamental cause of which is found in the location and movements of the centers of maximum and minimum pressure and that the change of direction in these currents is very similar to that of the atmospheric winds as determined by the barometric gradient. He also observes that the cirrus and cirro-stratus clouds which accompany migratory cyclones form angles with the direction of movement of the latter, dependent on the distance and direction from their centers.

[To face p. 391.]

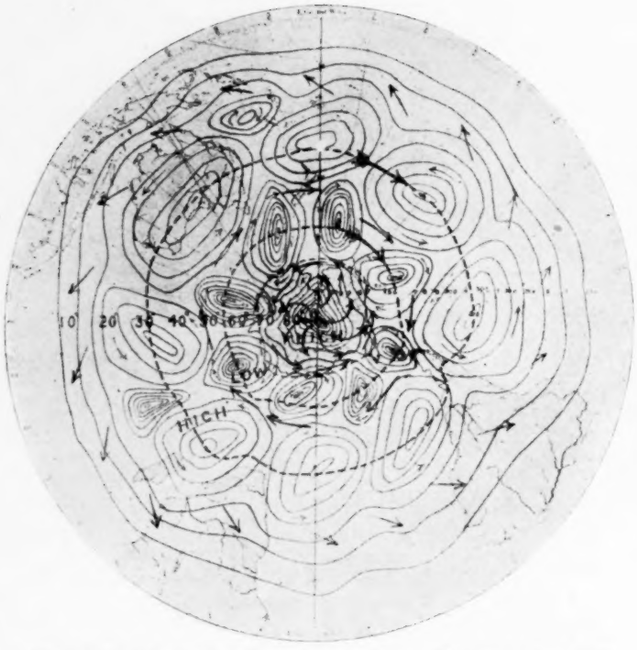


FIG. 1 (H. H. H.)—Southern Hemisphere circulation. (Lockyer.) (See p. 375.)

FIG. 1.—Union Schoolhouse, 5 miles west of Broken Arrow, blown down by the wind. Taken from the northwest. School library before the first window laid out to dry.

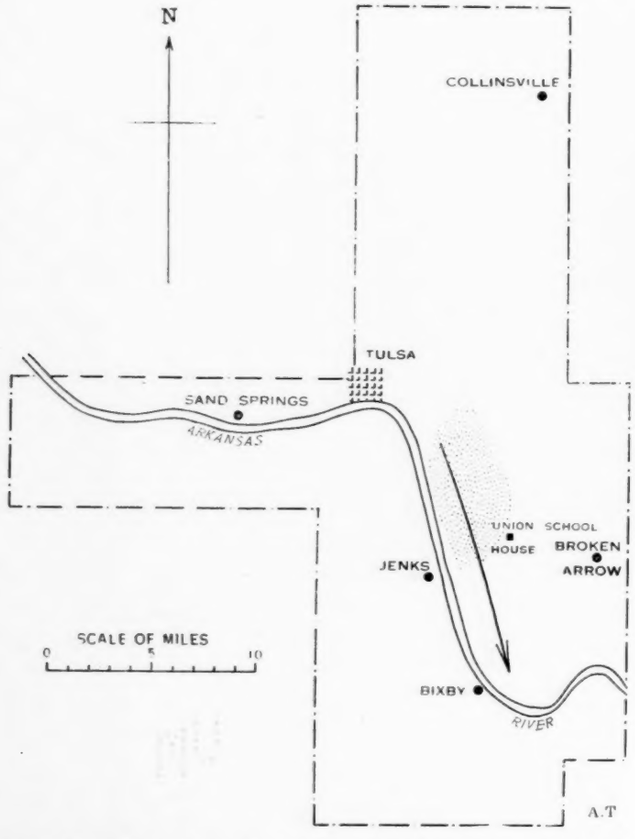


FIG. 2.—Map of Tulsa County, Okla., showing region of cloudburst of June 6, 1919. Arrow indicates region of destructive winds. Dotted area shows region of most violent hailstorm.

FIG. 3.—Home of E. L. Levin, 1602 South Boston Street. The flood swept this 6-room bungalow several yards from the foundation. The house was completely filled with water.

THUNDERSTORM AT TULSA, OKLA., JUNE 6, 1919.

By J. A. REIHLE.

[Dated: Weather Bureau Aerological Station, Broken Arrow, Okla, June 21, 1919.]

During the afternoon of June 6, 1919, the genesis and growth of a cumulus cloud through cumulo-nimbus into an unusually destructive thunderstorm were watched by the men on this station. As this storm started and attained its greatest fury within a few miles of this station it will be interesting to note the free-air conditions recorded shortly before the storm, especially since free-air conditions cannot usually be obtained by kites for several hours previous to such a storm on account of low wind velocities.

During the morning the wind was too light to sustain a kite, and the temperature rose from 14.5° C. in the morning to 31° C. in the afternoon. At 1:50 p. m. a south breeze became strong enough to start a kite flight, and at 3:33 p. m. an altitude of 2,691 meters above sea-level was reached.

A summary of the free-air data, computed by the Aerological Division, is given in Table 1. A notable feature of this table is the steep temperature gradient up to 1,500 meters. This condition was favorable to strong local convection; in this case, however, the gradients were scarcely sufficient to carry the rising air aloft to a point where condensation would occur. This saturation level would have been reached by convection ascent at an altitude of approximately 1,750 meters above sea-level, under the surface conditions recorded at 3:33 p. m., with a temperature of 30.4° C. and a dewpoint of 18.8° C. [$H_m = (t_a - t_{d.p.})/.0077$]. In the region where the cumulus clouds started these superadiabatic gradients must have extended upward sufficiently high for condensation to begin in the rising air. Then, once condensation had begun the gradients noted in Table 1 would have been sufficient for the continued upward movement of the saturated air, and the growth of the large cumulus clouds observed.

The wind, as determined by pilot-balloon ascensions at 3 p. m. on the 6th and at 7 a. m. on the 7th, is shown in Table 3.

TABLE 1.—*Free-air data from kite flight at Broken Arrow Aerological Station, June 6, 1919.*

Time.	Surface temperature.	Relative humidity.	At different heights above sea.							
			Altitude.	Pressure.	Temperature.	$\triangle t$ 100 m.	Humidity.		Wind.	
							Relative.	Vap. pres.	Direction.	Velocity.
P. M.	° C.	Per cent.	m.	mb.	° C.		Per cent.	mb.		m.p.s.
1:50	30.5	52	233	987.1	30.5	.....	52	22.71	s.	5.4
			250	.....	30.3	.....	53	22.89	s.	5.4
			500	.....	26.7	.....	62	21.72	s.	5.8
			750	.....	23.1	.....	71	20.07	s.	6.2
2:25	30.4	52	845	920.4	21.8	1.42	75	19.59	s.	6.4
			1,000	.....	20.2	.....	76	18.00	s.	7.4
			1,250	.....	17.7	.....	79	16.00	ssw.	9.0
			1,500	.....	15.2	.....	81	13.99	ssw.	10.6
2:52	30.4	52	1,531	849.3	14.9	1.01	81	13.72	ssw.	10.8
			2,000	.....	11.8	.....	67	9.27	sw.	16.1
3:06	30.8	51	2,216	782.7	10.4	0.66	60	7.57	sw.	18.6
			2,500	.....	8.8	.....	46	5.21	wsw.	19.7
3:33	30.4	50	2,691	738.6	7.8	0.54	37	3.91	wsw.	20.4
			2,500	.....	8.8	.....	49	5.55	wsw.	19.6
			2,000	.....	11.4	.....	80	10.78	sw.	17.6
3:57	30.3	51	1,979	804.6	11.5	0.92	81	10.99	sw.	17.5
			1,500	.....	15.9	.....	80	14.46	ssw.	13.2
4:21	31.0	50	1,282	873.4	17.9	1.01	79	16.20	ssw.	11.2
			1,250	.....	18.2	.....	78	16.30	ssw.	11.2
			1,000	.....	20.7	.....	70	17.09	ssw.	11.5
			750	.....	23.3	.....	63	18.02	s.	11.7
4:46	30.4	52	540	950.8	25.4	1.50	56	18.17	s.	11.9
			500	.....	26.0	.....	55	18.49	s.	11.6
			250	.....	29.7	.....	51	21.28	s.	9.5
4:52	30.0	51	233	984.2	30.0	.....	51	21.64	s.	9.4

TABLE 2.—*Clouds observed during kite flight.*

Time.	Amount.	Kind.	Direction.
	Tenths.		
1:50 p. m.	1	St. Cu.	sw.
2:21 p. m.	2	Cl. Cu.	w.
	1	St. Cu.	sw.
2:57 p. m.	1	Cl. Cu.	w.
	1	A. Cu.	w.
	1	St. Cu.	sw.
3:28 p. m.	1	A. Cu.	w.
	Few.	Cu.	w.
	1	St. Cu.	sw.
4:15 p. m.	Few.	Cu.	w.
	1	St. Cu.	sw.
4:46 p. m.	2	Cu. Nb.	w.
	Few.	St. Cu.	sw.

TABLE 3.—*Wind direction and velocity, by pilot balloons.*

Altitude above station (meters).	June 6, 3 p. m.		June 7, 7 a. m.	
	Direction.	Velocity.	Direction.	Velocity.
		m. p. s.		m. p. s.
Surface	S	5	ENE	3
500	SSW	5	SSW	9
1,000	SW	10	SSW	13
2,000	WSW	15	SW	13
3,000	W	18	.....	.....

NOTE.—Station elevation, 233 meters.

At 3:28 p. m. the summits of a few cumulus clouds began to appear. One anvil shaped cumulus was seen to the northeast, and a row of three or four mountainous peaks stretched away to the west. At 4 p. m. an immense cumulus cloud estimated to be 40 or 50 kilometers away to the west-northwest, with a summit extending through the alto-cumulus layer and to a considerable distance above it, began to show signs of precipitation, and at 4:42 p. m. the first thunder was heard. At this time there was a well-marked area of precipitation in the center of the cloud and the whole mass was moving slowly eastward.

As the storm approached it increased rapidly in size and a veil of false cirrus overflowed eastward and southward. Underneath the anvil portion which extended forward the cloud took a well-developed mammato-cumulus form. A continuous roar of thunder in the upper portion of the cloud was heard for perhaps half an hour before the arrival of the storm.

The storm moved from the west, i. e., with the wind at 2,500 meters altitude and higher, and covered Tulsa County and adjoining territory. The destructive violence was spread over several square miles, and extended from Collinsville on the north to Bixby on the south (see map). One child was killed at Bixby, several people were injured in various places by falling buildings, and damage to property and farm crops amounting to more than a million dollars was sustained. The damage resulted from a combination of wind, hail, and rain.

The anemometer at Broken Arrow recorded an extreme wind velocity from the north-northwest of 80 miles per hour (36 m. p. s.) and a maximum velocity for five minutes of 67 miles per hour (30 m. p. s.) at 6:28 p. m. Five or six miles farther west the wind appeared to have been more violent. A schoolhouse (fig. 1) and a large barn, just completed, were blown down, and several farmhouses and barns were unroofed. At

Bixby 20 houses were reported to have been demolished, and a number of oil tanks were damaged or blown away. This wind was not of tornadic character, but simply a straight blow with a front of 8 to 10 miles or more.

The heaviest rainfall, amounting in popular language to a cloudburst, fell in Tulsa, where 5.80 inches was recorded. At Broken Arrow 1.05 inches was recorded. These amounts are somewhat deficient on account of the high wind that accompanied the heaviest downpour. Hailstones 1 inch in diameter fell in Broken Arrow; in Tulsa one hailstone was found to measure 8 by 6½ inches in circumference, and another weighed 4½ ounces. The heaviest fall of hail occurred between Broken Arrow and Tulsa, shown by the dotted area on the map (fig. 2). Here the hailstones said to have been the size of hens' eggs fell in large quantity. Over a wide area in this section the hail caused almost a total loss of what had promised to be an abundant crop of wheat and oats. Corn was torn to shreds, gardens obliterated, and fruit, particularly peaches, of which there were a number of commercial orchards, was nearly all knocked from the trees, while even the bark was seriously injured by the hail.

The flood in Tulsa resulting from the excessive rain caused property damage amounting to thousands of dollars. Houses were moved from their foundations (fig. 3), and garages and automobiles were washed away by a torrent several feet deep that raged through the lower sections of the city.

TORNADO AT FERGUS FALLS, MINN., JUNE 22, 1919.

On the afternoon of Sunday, June 22, 1919, at 4:45 p. m., the town of Fergus Falls was struck by a tornado which, almost in a twinkling, razed 228 houses, killed 57 people, and injured many more.

From descriptions given by persons who saw the tornado as it approached the city it appears that it was accompanied by all the phenomena which characterize such storms—a black, funnel-shaped, "twisting" cloud, or several of them, a heavy downpour of rain, and a terrific roar. Mrs. Elsie Rathbun, who watched the storm from the Great Northern Railway Station, is quoted in the Minneapolis Tribune as saying that "the storm approached rapidly, with black clouds pushing up from the west toward the city. Just before it struck Fergus Falls there was a humming like a dozen factories all full of buzzsaws running at once, and then when the storm arrived there was a pandemonium of noise." Richard Krynen, according to the same paper, also watched the storm from the Great Northern station. He is quoted:

> For a considerable time before the tornado struck there was a rumbling sound, and then it started to rain and rained hard. We thought the rain was going to stop, but hailstones the size of marbles began to fall.[1]

Quoting from the Minneapolis Journal of June 23, 1919:

> The first storm, they say, struck the town from the northwest, and tore through the Lake Alice district. This was the one that wrecked the Grand Hotel. The second storm, which brought driving rain, approached from the southwest. A third, it is claimed, swept over the eastern portion of the town from the southeast, but did less damage.

Fergus Falls, with a population of 12,000, is situated in northwestern Minnesota. The town is divided into two sections, north and south of the Red River. It was the north portion that was demolished. See figures 1 and 2.

Telegraphing over hay-bale wire from Fergus Falls two days after the tornado occurred, Carlton W. Miles, of the Minneapolis Journal, said:

"Half the town looks like a vast acreage of kindling; the other half, save for trees split at the roots, is unharmed."

But while it is true that only half the town was demolished, the line of wreckage could be clearly traced for a distance of 10 miles to the east, and a bank check was picked up 60 miles away. The property loss was $3,500,000, of which $500,000 was in automobiles, many of which were caught by flying débris. In one instance the force of the wind split a huge tree, threw an automobile into the intersection, and then closed up the opening, holding the machine like a vise.

The following are some of the remarkable freaks of the tornado as recorded in the Minneapolis Journal of June 23, 24, and 25, 1919:

Wind force.—A trunk with clothing was carried from the residence of E. T. Barnard into the attic of a house two blocks away. The trunk was found uninjured.

A slender weed was driven 6 inches into a heavy plank.

Clover leaves were driven into the plaster in many residences on the north side of the river.

The Great Northern "Oriental Limited," west-bound, was traveling between 30 and 40 miles an hour when the twister struck the baggage car behind the tender when about 6 miles east of Fergus Falls, throwing 7 of the 11 coaches from the rails. The baggage car was torn out of the train and set down about 30 feet from the rails at right angles to them. The suction also tore out the track under this car.

Suction (explosive expansion of air as low pressure of tornado passed).—In homes where there were stained-glass windows, the colored portion is intact although the regular window glass is broken.

In many homes all the clothing stored in closets disappeared in the storm.

In one flock of 30 chickens all their feathers were stripped off, and the chickens were found in the henhouse sitting up stiffly at attention. All of them were dead.

Agnes Palm, the little daughter of August Palm, was sitting on her father's lap in their home on the east side of Lake Alice. The father, mother, and sister were killed, but little Agnes escaped injury, although her shoes were torn from her and she was set down a short distance away.

Localization of damage.—Three houses stand alone on Cleveland Avenue north. The top story of each is sliced off as clean as if with a cleaving knife.

In the Knoff residence a cut-glass vase was carried from its resting place on a buffet over a pile of dishes, around a corner into the living room and was found unbroken on the floor.

The Levorsen house on Lakeside drive was so badly damaged that it was deemed unsafe to enter it. * * * All the furniture was in splinters except the buffet, which was moved 2 feet from the wall with not a dish broken.

In one house every stick of furniture was destroyed with the exception of the piano and a talking machine, which were not even scratched.—*H. Lyman.*

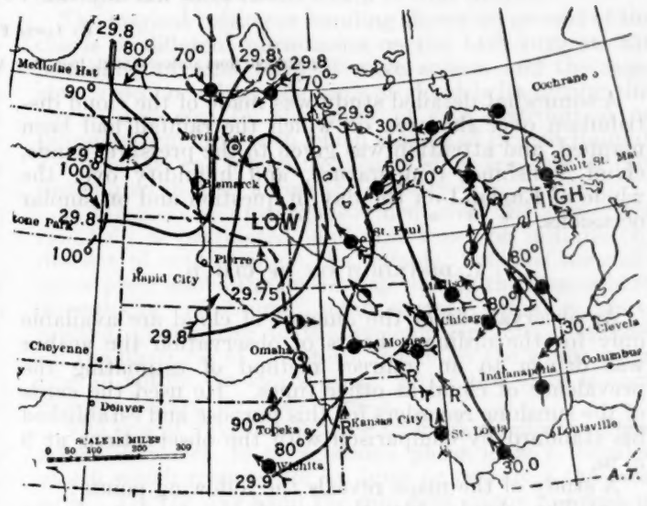
[1] The *Literary Digest*, New York, July 26, 1919, pp. 38 and 40, has a detailed account of this storm and the damage wrought.

FIG. 1.—View of tornado damage in Fergus Falls, Minn. Note the trees stripped of bark, probably by the explosive action of the air in the bark, as the low pressure of the tornado passed. (*Courtesy, Minneapolis Journal.*)

FIG. 2.—Tornado destruction along Red River in Fergus Falls, Minn.

DISCUSSION.

The weather map showing the conditions two hours after the tornado occurred (fig. 3) fails to indicate any large cyclone or low-pressure system such as is usually associated with the occurrence of tornadoes. In this case, there was a small LOW with generally moderate winds. The weather in front of the center was cloudy and cool, while that in the rear was warm, hot in the southwest quadrant. Intermediate clouds at Minneapolis (Ci.Cu., SE.) and Duluth (A.St., S.) moving from the south indicated, perhaps, an unusual depth to the cyclonic circulation. Since violent convection is necessary to the production of tornadoes and such severe thunderstorms as were experienced through central and southern Minnesota in the afternoon and night of the 22d, it seems reasonable to suppose that the cool southerly and easterly winds of the front half of the cyclone overran, in part at least, some of the warm winds in the rear half, thereby producing steep vertical temperature gradient. Or the hot winds of the southwest quadrant may have underrun the cool winds of the southeast. One is led to wonder whether the movement of the thunderstorms toward the region with cool weather instead of away from it as is usual had anything to do with their extreme severity.—*C. F. Brooks.*



IG. 3.—Weather map, 6 p. m. (90th meridian time), June 22, 1919. Dot shows location of Fergus Falls. Barbs on arrows show wind velocities in Beaufort unbrsem. (*Courtesy, Minneapolis Journal.*)

HAILSTORMS IN SOUTH CAROLINA, JUNE 8 AND 9, 1919.

By RICHARD H. SULLIVAN, Meteorologist.

[Dated: Weather Bureau, Columbia, S. C., July 5, 1919.]

FIG. 1.—Hailstorms in South Carolina, June 8-9, 1919.

On the basis of newspaper reports of hailstorms published on June 9 and 10, 1919, inquiries were sent to postmasters and others in the affected areas.

FIG. 1.—Hailstorms in South Carolina, June 8 and 9, 1919.

The most destructive storm was in southern Sumter and northern Clarendon counties, where the damage to growing crops approximated $262,000 in a region 5 by 20 miles on the county line, in the neighborhood of Brogdon and Harvin. The general hail area extended from near Lykesland, in eastern Richland County, to near Olanta, in western Florence County, and from central Sumter County to central Clarendon County in greatest breadth, or approximately 25 by 50 miles. The hailstones ranged in size from pebbles or small marbles to hen eggs, the storm culminating between Brogdon and Harvin, where growing crops were damaged probably 30 to 80 per cent, and in isolated instances probably 100 per cent. As in most cases of hail damage, magnified by large heads in the newspapers, the area of total hail damage is comparatively small, and crops frequently recover to full fruitage in large areas after the storm, as in the case of the great hailstorm in the northern part of this State in July, 1914, which was the most widespread and destructive of record in this State.

In York County, the path of the hailstorm of the afternoon of the 8th was 1.5 to 12 miles in extent, beginning at a point west of Bowling Green and running eastward and thence southeastward toward Fort Mill. The hailstones were mostly small, according to the postmaster at Bowling Green. The total damage was estimated at $50,000 to $65,000.

The second storm in York County during the afternoon of June 9 was only 0.5 to 3.0 miles in extent, in a path about 3 miles south of the town of York. The hailstones ranged from peas in size to 1 inch in diameter. The damage approximated $35,000.

Figure 1 shows the location and extent of these storms.

SUGGESTIONS AS TO THE CONDITIONS PRECEDENT TO THE OCCURRENCE OF SUMMER THUNDERSTORMS, WITH SPECIAL REFERENCE TO THAT OF JUNE 14, 1914.

By JAMES FAIRGRIEVE.

(Quotations from abstract Quart. Jour. Roy. Meteorological Soc., 1918, vol. 44, pp. 245-252.)

A somewhat detailed study was made of the cloud distribution over the area on which the rainfall had been mapped, and attention was given to the pressure, winds, cloud, sunshine, temperature, and humidity over the whole of England on the day in question and on similar occasions. * * *

1. DISTRIBUTION OF CLOUD.

As observations of the amount of cloud are available only for the ordinary hours of observation the author was driven to an indirect method of estimating the prevalence of cloud at other times. He used the cards of the sunshine recorders for this purpose and established his standard by comparison with the observations at 9 a. m.

A study of the maps reveals the following points:

(*a*) The clouds, like the rain fields, tend to lie in belts. * * *

(*b*) Cloud belts foreshadowed the rain belts, sometimes by several hours. * * *

(*c*) The cloud belts tend to increase and decrease repeatedly over the same area. * * *

(*d*) As with the rain belts it was only on the south coast that the cloud belt extended westward quickly; it was not till between 2 and 3 p. m. that the sky north and northeast of Mid-Hampshire began to cloud extensively, though the cloud belt had extended along the south coast by 11 a. m.; by 5 p. m. the same region was showing signs that the cloud was becoming thinner than elsewhere.

(*e*) In the London district after the storm developed the cloud quickly thinned to the north and to the southeast. * * *

2. METEOROLOGICAL CONDITIONS OVER ENGLAND.

(*a*) *Pressure.*—On the 14th, and for some days previously, pressure was highest to the northwest of the British Isles in a ridge connecting the Atlantic anticyclone with an area of high readings over Scandinavia, and was low over France and Germany. * * * The general trend of the isobars was parallel to the belts of cloud and rain.

(*b*) *Surface winds.*—The winds at 9 a. m. * * * were generally from the northeast with some minor irregularities.

(*c*) *Cloud.*—* * * Over the northwest of England and Wales the sky was very clear, while the cloud was densest on the east coast. Over the central and southern part of the country a series of bands of cloud, roughly parallel to the isobars, is shown. The duration of sunshine for the day over the British Isles has similar features.

(*d*) *Dew point.*—The temperature of the dew point at 9 a. m. was worked out for England and Wales; the highest values were in the southeast and lowest in the northwest. Just north of London the dew point was over 62° F., and it decreased to less than 42° in northern Lancashire. The plottings were unusually accordant.

(*e*) *Temperature.*—At 9 a. m. the distribution of temperature was similar to that of cloud; but it is doubtful whether the correspondence is of importance. It is probably due to the fact that where the sun had been shining for some hours the surface temperature was raised.

(*f*) *Minimum temperature.*—The minimum temperatures of the previous night were also plotted. The author suggests that some of the irregularities in the direction of the wind are associated with the areas in which temperature had been lowest a few hours earlier.

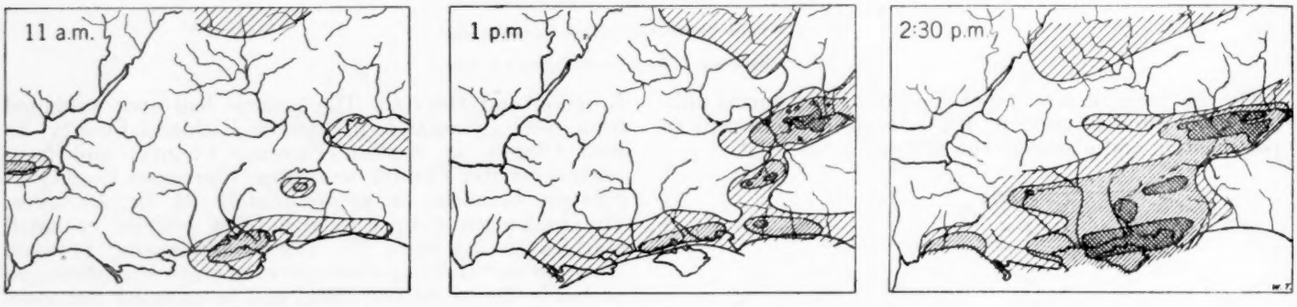


FIG 1.—Cloudiness and rain in south England, June 14, 1914. No shading=clear; light shading=partly cloudy; heavy shading=cloudy; cross-hatching=rain falling.

3. CONDITIONS ON OTHER THUNDERSTORM DAYS.

The author has also examined the incidence of minimum temperature on other days on which thunderstorms occurred, including May 31, 1911, the "Derby Day" thunderstorm, and July 1, 2, 3, and 4, 1914. The inquiry suggests some connection between the distribution of minimum temperature and subsequent thunderstorm phenomena, but the indications are not very definite.

4. THE LONDON DISTRICT.

(*a*) *Hail.*—About 70 observers in the London district sent in reports on falls of hail. Very little hail fell north of the river, and none of any consequence in the southwest of the storm area. The hail fell in more or less detached areas, and seems to have fallen in four or five bursts and not over large areas at one time. * * *

(*b*) *Wind movement.*—Outside the immediate storm area the general northeasterly direction of the wind was maintained, but the winds were probably rather lighter in the south than to the north. Several irregularities are reported within the area. * * *

(c) *Cloud movement.*—The evidence as to wind movement in the upper air is very scanty, but what there is is interesting. To the north of the storm, at Barnet, the lower clouds were consistently from the northeast or east-northeast, the higher clouds, said to be cirrus, being from the east or south-southeast. "From 2 to 8.30 a constant procession of embryo cumulus passed south of Barnet and seemed to attain development south of that place." Only one important cumulus passed north of Barnet. This agrees with the author's own recollections of the occurrences seen from New Southgate, a little nearer the storm area. At Barnet by 1 p. m. a large pile of cumulus with brilliant protuberances was seen to the south-southeast, beginning to "fan" slightly at the top. It may be noticed that this time agrees with the first fall of hail on the north of the storm.

From Warlingham on the south of the storm magnificent thunderheads were seen at 2 p. m. to the north. This again agrees with the time when hail occurred in the center of the storm. Later, a large anvil-shaped cloud rose up behind the other clouds. From Purley about 3.30 a large cloud pillar was observed 18° east of north and 25° high. Assuming that this was 8 or 9 miles away, the height would be about 3 miles. This rose and merged into the upper cloud.

Within the storm or on its southern margin at New Malden the lower thundercloud moved very slowly from east-northeast, but the "upper cloud" was seen during a lull in the storm to be moving from the south.

5. CONCLUSIONS.

In the concluding section of the paper the author discusses the bearings of the facts elucidated on the causes of thunderstorms, and also on the causes responsible for starting storms when conditions are favorable, but he points out that the connection between the facts and the views which he adopts is not very clearly made out. He agrees with Lieut. Douglas that the conditions necessary for summer thunderstorms are produced at some height above the surface,[1] say about 3,000 feet, that they may be started by conditions below that height, and that surface wind phenomena and temperature phenomena, such as the fall of temperature almost simultaneously with the beginning of the storm, are the results and not causes. It would seem probable that a necessary condition for the occurrence of a thunderstorm is that the temperature should decrease at a rate not less than normal, i. e., that the lapse rate should be about 3.5° F. per 1,000 feet for a considerable distance upward, and refers to a suggestion by Lieut. Douglas that this should occur for a height of 6,000 feet from half a mile above the ground. Cirrus, possibly false cirrus, is usually, if not always, present, and when the cumulus reaches a height of 3 to 4 miles its top spreads out. * * *

The author thinks that local surface conditions, such as the relief of the ground, may determine the start of a storm; the high ground of Leith Hill and Hindhead may have given a start to the storm in that district.

The marked belting or banding shown on several of the charts of different phenomena on the 14th suggests the possibility of some form of wave action, and the same idea is supported by the lines of cloud belts during this storm, and also by the maps of rain distribution on thunderstorm days with which readers of British Rainfall are familiar, and which frequently show splashes of rain distributed in lines across the country.[1]

If this is so, an upward movement over the area of the rain field is postulated, and this must be initiated by descent of cooler air on the outside, but this normally takes place above the lowest half mile in the atmosphere. Eventually, of course, some surface air does move inward, giving rise to the cyclonic circulation noticed on the outskirts of the storm, while on the whole calms prevail within the storm area. Later this calm is occasionally broken by violent gusts.

The first of "cyclonic" phase seems fairly clear. There seems, however, to be a second phase in any thunderstorm which remains for an hour or two over the same area. On the one hand the rain field seems to break up into two parallel belts, and on the other the surface wind seems to blow *from* the storm. It seems to be the case also, if we can generalize from two investigations, that the more vigorous of the two belts of rain field into which the storm breaks is on the side from which the wind is naturally coming. On June 14, 1914, the wind on that side, the northern, had a much greater surface velocity. This seems to suggest that the reason for the greater activity has to do with a greater supply of air on that side. As far as any surface observation is concerned this air seems to disappear. The logical inference is that it must be rising. It is possible that the projections of the rain field northwards, e. g., at about 3.45, along neither of the dominant axes may be due to the rising of this air in patches rather than along a continuous front.

As to the breaking up of the storm into two belts the following suggestions have been made. When rain or hail forms, it is said, pressure will first decrease immediately below the point of formation. The rain on falling will reach a terminal velocity. The air through which it passes will be cooled and contract, i. e., become heavier, and pressure will increase. At first these winds will tend to flow inward, and later they will tend to flow out. On this assumption the violent gusts at the surface in the center of the storm during the later stages are due to the descending air. * * * All this goes to show that the rain area was a local high pressure area during the later stages of the storm.

In any case the evidence of the surface winds must be taken into account. As these seem in the later stages to be blowing from the storm it is fair to infer that the pressure is greater along the middle line than on the outskirts.

[1] Douglas, C. K. M., "The lapse-line and its relation to cloud formation," Edinburgh, J. Scot, Meteor. Soc., 17, 1917, pp. 133-147.

[1] Not necessarily from moving storms.—C. F. B.

WIND STRATIFICATION NEAR A LARGE THUNDERSTORM.

By LESLIE A. WARREN.

[Dated: Weather Bureau Aerological Station, Broken Arrow, Okla., June 25, 1919.]

The accompanying horizontal projection curve of a pilot balloon ascension begun shortly after 3 p. m. on June 20, 1919, at the Broken Arrow Aerological Station (fig. 1) reveals an unusual and very interesting wind condition. The balloon in attaining an altitude of 7,000 meters made three nearly complete reversals in horizontal direction, corresponding to two counter-clockwise whirls which are evident upon the projection. The balloon, after release was carried upward in a light easterly wind until an altitude of 1,500 meters was reached where

an abrupt change into a north current occurred. Drifting in this current for 800 meters ascent at an extremely low velocity, the balloon was then carried along in a westerly wind changing to southwest from an altitude of 2,300 meters. The wind direction for the next 1,300 meters ascent as indicated by the balloon's course

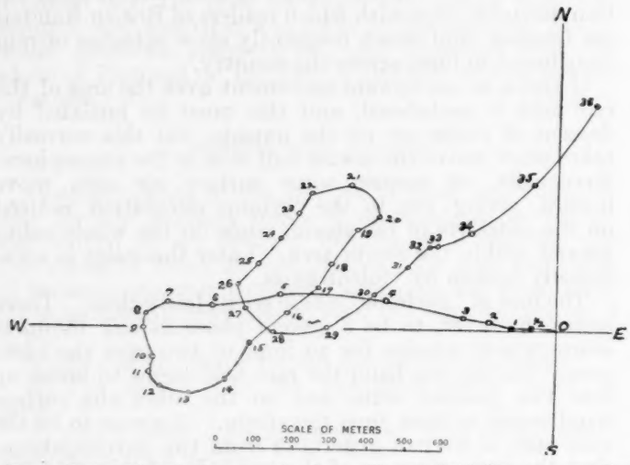


FIG. 1.—Horizontal projection curve showing position of pilot balloon at consecutive minutes.

remained fairly steady from the southwest, then backed to northeast about 400 meters higher. The direction continued from the northeast through an air layer about 1,000 meters thick and again changed through northwest and west to southwest at an altitude of 5,500 meters, and remained fairly steady to the 7,000-meter level where the balloon was lost to sight in a cirrus haze.

Except for short periods the wind velocity as computed was very light. A minimum velocity of 0.6 meter per second at the 2,000-meter level and a maximum of 4.4 meters per second at the highest altitude attained, were found to exist.

This rare atmospheric condition is thought to be closely associated with a thunderstorm which began at 7 a. m. of the same day and continued until a few minutes before the beginning of the balloon run. The sky which had been totally obscured during most of the day with heavy nimbus and cumulo-nimbus clouds began clearing rapidly about 20 minutes before 3 p. m. And in a comparatively short time the lower clouds had disappeared and a variety of upper cloud formations had appeared. The apparent counterclockwise whirling motion of the atmosphere tends to make more pronounced the close connection with the thunderstorm.

The wind blew directly toward the thunderstorm until within an hour of the beginning of the balloon run. The thunderstorm approached from the south-southeast, and as the exceedingly large mass of cumulo-nimbus clouds passed off the wind changed from north-northwest to northeast, east and, finally, when the cloud mass was away toward the northwest horizon it had shifted to the southeast from which it had changed during the first signs of the storm.

Consulting the weather map of 8 a. m. June 20, 1919, it is easily seen by the indicated wind direction at the several stations surrounding Broken Arrow that this station was near the center of a counterclockwise atmospheric circulation. Supposing that this whirl continued with altitude, it seems very probable that the whirls in the balloon's path were also a part of this circulation of greater magnitude.

The inevitable over-and under-running of these converging winds would undoubtedly account for many of the wind differences aloft, while the local thunderstorm winds such as outflow below and above and inflow at intermediate levels would add to the complexity. The counterclockwise direction of the balloon's path being cyclonic also suggests rising air.

Thus it seems that the balloon whirls, the thunderstorm, and the atmospheric circulation indicated on the weather map were in all probability closely interrelated.

PRESSURE FLUCTUATIONS DURING A THUNDERSTORM.

Father E. F. Pigot, S. J., of Riverview College Observatory, Sydney, New South Wales, has kindly transmitted to us the accompanying copy (fig. 1) of a record

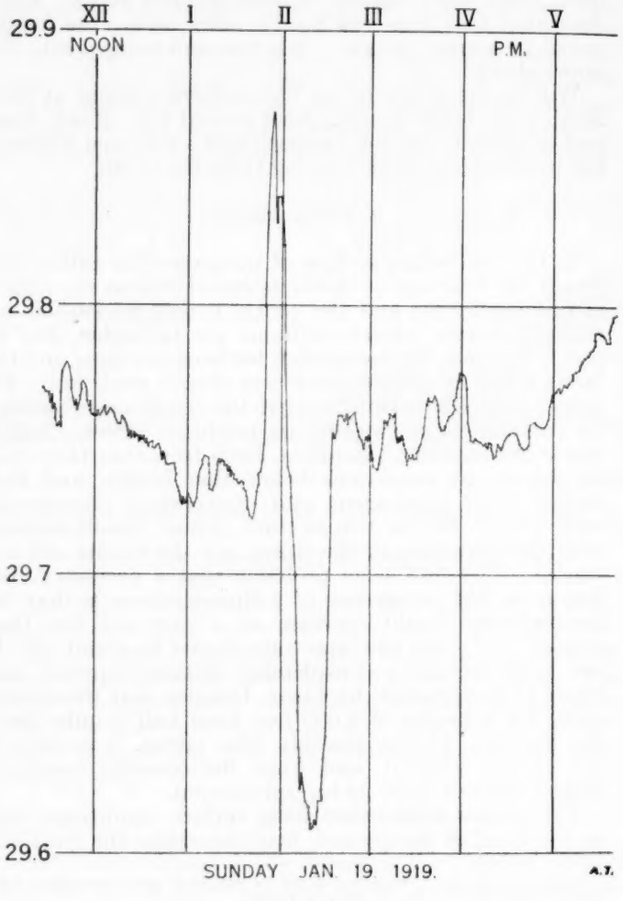


FIG. 1.

from a Murday microbarometer showing the large and rapid fluctuations of atmospheric pressure during the passage of a heavy thunderstorm and squall at Sydney, New South Wales, on Sunday, January 19, 1919. The record is in the form of dots, made at intervals of one minute.—ED.

FIG. 1 (J. R. W.).—Mammato-cumulus clouds in west and northwest at 7:44 and 7:44½ p. m., June 24, 1914, Binghamton, N. Y.

FIG. 2 (J. R. W.).—Mammato-cumulus clouds in northwest at 7:48 p. m.

(To face p. 397.)

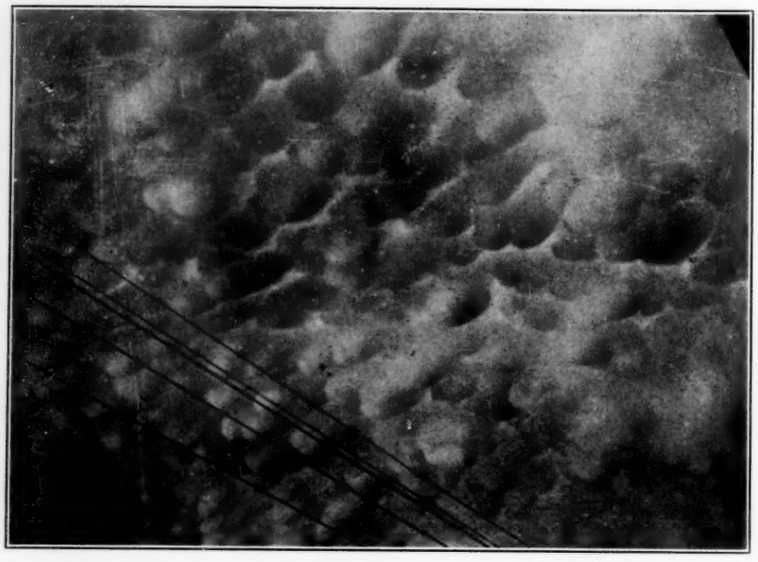


FIG. 1a.

FIG. 1b.

FIGS. 1a and 1b.—Mammato-cumulus formation associated with tornado. Photograph by L. C. Twiford, Bartlesville, Okla., June 15, 1912, 6:30 p. m.

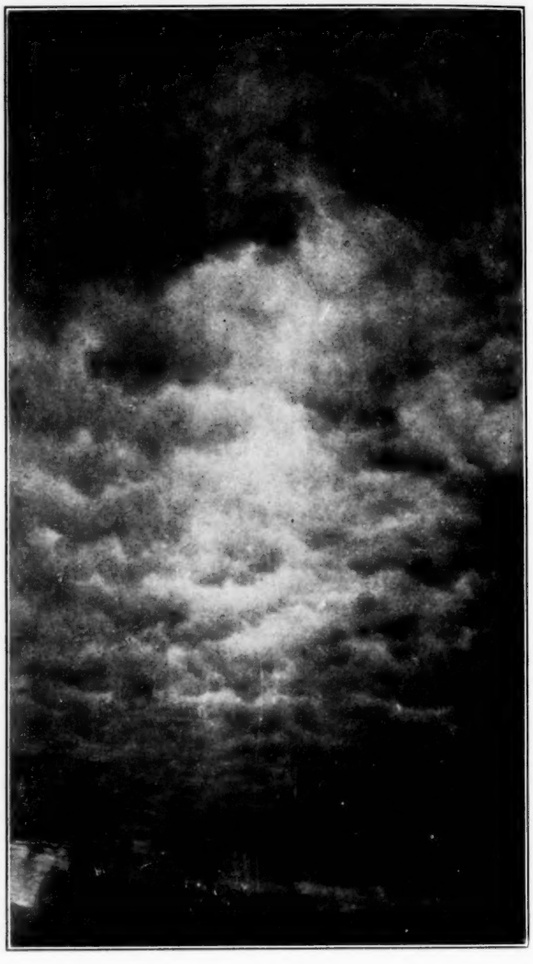


FIG. 2.—Mammato formation on under boundary of warm wind. Washington, D. C., Feb. 28, 1919, 7:10 a. m.

FIG. 3.—Mammillated squall cloud (G. A. Clarke).

MAMMATO-CUMULUS CLOUDS AND THUNDERSTORM AT BINGHAMTON, N. Y., JUNE 24, 1914.

By JOHN R. WEEKS, Meteorologist.

[Dated: Binghamton, N. Y., July 7, 1914.]

Soon after 6 o'clock in the afternoon of June 24, 1914, the typical thunderstorm cloud formation appeared in the west, and by 6:30 p. m. the sky was overcast with boiling storm clouds. From 6:30 p. m. to 6:45 p. m. a light shower occurred, the rain drops being large and widely spaced. The splash made by each drop was about 2 inches in diameter. The first thunder was heard at 6:20 p. m. and occasional peals of thunder continued until 7:58 p. m. At 6:55 rain set in again, accompanied at 7:05 p. m. by a wind velocity of 34 miles per hour from the west for three or four minutes. The rainfall became excessive at 7:08 p. m. and continued excessive until 7:18 p. m., when it became light again and ended at 7:40 p. m. The total rainfall was 0.82 inch and during the 10 minutes ending at 7:18 p. m. an estimated amount of 0.60 inch fell.

The sun broke through the clouds on the western horizon at 7:25 p. m. and a double rainbow appeared in the east. There were at that time no mammato-cumulus clouds visible. At 7:38 p. m. the sun had set (astronomical sunset 7:43) and mammato-cumulus clouds were just beginning to become visible on the western edge of what then appeared to be a stretch of alto-stratus clouds covering the sky from near the western horizon eastward until it mingled with the storm clouds then passing off in the east.

Fourteen photographs were taken in the interval from 7:40 p. m. to 7:55 p. m. (see figs. 1 and 2). During that time the visible mammato-cumulus formation increased until it covered the entire sky at 7:43 p. m., and a second thunderstorm made its appearance in the west, passed beneath the mammato-cumulus clouds, and at 7:56 p. m. was over and to the south of the observer.

The alto-stratus cloud layer in which the mammato-cumulus clouds formed was moving eastward at what seemed to be about half the velocity of movement of the second thunderstorm. In the southeast and south the alto-stratus layer seemed to merge into and become part of the storm cloud. The mammato-cumulus clouds first made their appearance at the western edge of the alto-stratus layer as downward bulges in the cloud film. The number of bulges increased toward the east until the sky was nearly covered. There was no evidence of rotary movement in any of the pouches. They seemed to be downward bulges in the cloud stratum and each pouch persisted for some time, appearing gradually and dissipating gradually. Under a few of the pouches in the early stages of the phenomenon there was a distinct veil following the outline of the pouch, such as a scarf cloud which sometimes appears over a rounded thunderhead. Overhead and in the east toward the close of the phenomenon there were both pouches and what appeared to be holes in the cloud stratum where pouches had been. The pouches were tinted pink from the twilight glow. The "holes" were a dark greenish blue. Both pouches and holes seemed quiescent, except for eastward movement, and the holes had the size and appearance of having been made by the dissolving away of some of the pouches. At the same time in the north, above the advancing storm clouds of the second thunderstorm, was observed (among the mammato-cumulus) a cloud wave of small extent that appeared as though a cross-section had been made of two adjacent pouches and the front section removed. That is, there was a downward hollow, a ridge, and then another downward hollow, the two downward curves being of the same size and shape as the cloud pouches of that portion of the sky. The section was as sharp and well defined as if cut with a knife. An attempt was made to photograph this but the light had failed so rapidly that a considerable under-exposure resulted.

There was a considerable and distinct stratum, except in the east and south, of cloud-free air between the mammato-cumulus clouds and the thunderhead clouds that passed beneath them. There was a strong contrast between the quiescence of the mammato-cumulus clouds and the quick "boiling" of the lower clouds.

At 7:56 p. m. the center of the second thunderstorm was in the hills south of the observer. Lightning emerged from this center, passed to the alto-stratus and mammato-cumulus cloud layer and spread through this in much the same manner as the spark from an electrical machine spreads over the surface of a glass plate. There were innumerable branches to each discharge and these branches had the appearance of running along the under-surface of the alto-stratus layer and of going behind and between the mammato-cumulus pouches. The sight was a remarkable one but was, unfortunately, too evanescent for a photograph to be obtained.

The barograph trace shows a rise at 7:05 p. m. of 0.15 inch, followed quickly by a fall of 0.10 inch and then a more gradual rise and fall of 0.05 inch. The temperature trace shows a fall of 20° at 7 p. m. to 65° F., followed by a gradual rise to 69° by 9 p. m. The (surface) wind velocity was but 3 miles per hour from 6:25 p. m. to 6:45 p. m.; increased to 34 miles per hour at 7:05 p. m., and diminished again to a little less than 3 miles per hour from 7:20 to 7:45 p. m. During the first thunderstorm the wind was mainly from the southwest, while during the mammato-cumulus cloud phenomenon the surface wind was mainly from the east and northeast and the upper wind from the west.

The photographs (figs. 1 and 2, enlarged in reproduction) were taken with an f. 4.5 lens of 75 mm. focus with exposures of one twenty-fifth to one thirty-fifth of a second. The photographs are unable to show the delicate (sunset) color shades and contrasts that added to the distinctness and beauty of the phenomenon.

TYPES OF MAMMATO-CUMULUS CLOUDS.

By CHARLES F. BROOKS, Meteorologist.

[Dated: Weather Bureau, Washington, Aug. 2, 1919.]

SYNOPSIS.—The appearance of mammato-cumulus clouds, whether formed at high or low levels, shows that they are formed by local downward thrusts of air. Those associated with overflow sheets of thunderstorms are obviously formed of snow, which accounts for the slowness with which they change shape. While minor developments are not uncommon, the large, well-developed festoons of this class are associated only with the most severe thunderstorms.

On the boundary between two general winds, interference and initial condensation of moisture as a result of the projection of masses of the upper mammato-cumulus into the lower wind, occasionally form. If the upper wind is the colder, convection quickly destroys the mammato formation. If the lower current is already cloudy, cold air from above, especially if dry, may blow "cheese holes" through it.

The most impressive mammato-cumulus is the low, downward boiling cloud surface which marks the top of a cool, squall wind.

INTRODUCTION.

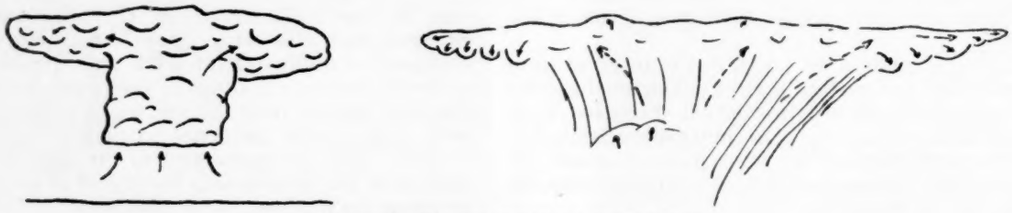
A mammato-cumulus cloud is one with downward bulges rather similar to a cumulo-form cloud upside down. "Mammato-cumulus" has been adopted internationally as the term designating this cloud type. Many other descriptive names for it are in use. In view of the fact that mammato-cumulus forms occur on the undersurfaces (1) of the spreading top sheets of cumulo-nimbus and remnant "false" cirrus, (2) stratus or alto-stratus, and (3) strato-cumulus or cumulus, some observers have sought to name the quiescent, high, snowy mammato-cumulus associated with false cirrus, "globo-cumulus,"[1] or "mammato-cirrus,"[2] and the low types, "mammato-cumulus," or if in violent commotion, like downward boiling, "mammillated squall cloud."[3] Durand Gréville has proposed "mammatus" as a generic term to designate clouds of downward motion, just as "cumulus" designates clouds of upward motion.[4]

MAMMATO-CUMULUS FORMED ON OVERFLOW CLOUDS.

The figures on the plate facing page 396 and figs. 1a and 1b (facing p. 397) are photographs of the mammato-cumulus on the undersides of overflow sheets from the tops of intense thunderstorms, and figure 5 shows diagrammatically the positions of the festoons relative to other parts of the overflow sheet and the probable air movements as indicated by observations of the development of the cloud form illustrated. (Figure 4 shows much the same movements in some strato-cumulus.) Many observers have independently arrived at the conclusion that these festoons are of falling snow (or ice spicules) and that the downward bulges are formed by the downthrust (or settling) of the cold, snow-filled air which is spreading out laterally at the tops of the cumulo-nimbus. It is colder than the clear air at the same level, and so settles into it, because the inertia of the rising air in the cumulo-nimbus carries it beyond the level of equilibrium. On going this additional amount higher it is cooled still more by expansion, but on descending again evaporation of the snow probably prevents any appreciable warming by compression. Occasionally the festoons may be formed by descent of cold air through an already-existing cloud sheet.

Where the downward movement is stronger, i. e., in the center of the festoon, the snow will evaporate most rapidly, and may disappear entirely, as described by Mr. Weeks (p. 397 above). The down-thrusting cold air may by mixture produce a filmy cloud, which gives the festoons a smoother aspect while they still look solid, and which preserves the outline even after the interior has evaporated.

The air between the down bulges must be rising as it is displaced. At times well-defined curls may be seen developing as the middle comes down and the sides go up. Ultimately the festooned false cirrus presents a ragged appearance, with snow still falling apparently only from the parts which were between the festoons. Such snowfall may be intensified by the expansional cooling of the rising air around the festoons: and even before the festoons themselves have begun to break up by evaporation this new snow may begin to veil them.



FIGS. 4 and 5.—Mammato formation in overflow sheets.

The snowy mammato-cumulus is strikingly developed only in the neighborhood of an intense thunderstorm and then more frequently in the rear than in front. When in front it is an ominous sign of the coming storm, which is likely to have tornadoes associated with it. Prof. H. C. Frankenfield states that shortly before the tornado at St. Louis, May 27, 1896:[5]

> The clouds slowly increased in density, and at 3:35 p. m. the sun was obscured. The character of the clouds changed about this time to cumulus, but of a very peculiar formation. The whole sky was compactly covered with small cumuli of almost perfect hemispherical shape, but with the rounded portions underneath. Their color was a dark gray with deep shadows on the sides farthest from the sun. By 4:30 p. m. these clouds had settled into a uniform covering of stratus, which commenced to assume a light green color. * * * [Rain began at 5:43 p. m. The tornado went by at 6:18.]

Also in the case of the clouds (figs. 1a and 1b, plate facing p. 397), photographed by Mr. L. C. Twiford, at Bartlesville, Okla., June 15, 1912, 6:30 p. m., possibly 45 minutes before the clouds were seen a tornado did great damage about 20 miles away, and in the direction from which the clouds came.[6]

[1] Poey. Classification des Nuages, Paris, 1873, p. 97.
[2] E. Durand Gréville. Le Mammatus, Bull. Soc. Astr. de France, Jan., 1901, 8 p. 6 figs.
[3] G. A. Clarke [British] Met'l Off. Circ. 29, Oct. 23, 1918.
[4] Loc. cit.
[5] MONTHLY WEATHER REVIEW, 1896, 34:77.
[6] From short article, "Mammato-cumulus clouds," by W. J. Humphreys, MONTHLY WEATHER REVIEW, 1912, 40:967–968.

The more common formation of mammato-cumulus in the rear of a thunderstorm may be due to the more favorable conditions for downward air movement there than in front. In front, the upper wind generally removes rapidly the overflow air and so stretches it out that the downward currents have little chance to become localized and well-defined.

Small snow-festoons seem to be formed locally under almost all cumulo-nimbus overflow sheets,* and are seen nearly as often as the sun shines under thunderstorm top (false cirrus) remnants at sunset tipping the festoons with light yellow and pink. Their not infrequent presence in summer adds great beauty to our warm-season sunsets.

MAMMATO-CUMULUS ON WIND BOUNDARIES.[7]

Mammato-cumulus formations on wind boundaries are usually ephemeral sights. They seem to mark the first stage of interference when the contrast between the two over- and under-running currents is strongest. Then if at least the warmer of the winds is saturated, or nearly so, projections of the upper wind into the current below will form mammato-cumulus by mixture.

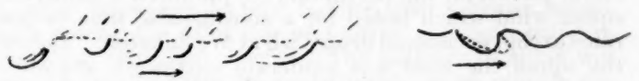
When the upper current is colder than the lower, convection attends the mixing. The centers of the down-bulges may soon evaporate as the descending

FIG. 6.—"Cheese holes" in St.Cu. overhead, Washington, D. C., Apr. 14, 1919.

air warms by compression; and the inter-bulge portions of the cloud thicken with condensation as the rising air cools by expansion. Thus, in the course of a few minutes the sky may have changed from a smooth rounded mammato condition to the ragged semblance of an inverted choppy sea, and shortly this ragged condition may fade behind a haze of rain or snow beginning to fall from the convectional clouds formed between the original festoons. All three stages are sometimes visible at the same time in different parts of the sky (e. g., 7 p. m., July 9, 1919, at Greenwich, Conn., lower wind, south, upper, west).

At times when the lower wind is already cloudy, down-thrusts of a cooler wind above tend to drive "blow holes" through the cloud. Large groups of slowly downward moving and spreading light spots (see fig. 6) develop and fade away in perhaps 20 minutes moving with the alto-stratus or stra.-cumulus covering across the sky. Here and there slowly forming curls, all anticyclonic, confirm the other impressions of downward movement. On April 14, 1919, snow (apparently) could be seen falling from between the light spots and two hours later light rain fell at the surface. When the cloud sheet is thin the down currents may make clear holes through it. Such a formation resembling exquisitely a thin lenticular slice of large-holed Swiss cheese was observed at 1:30 p. m., October 25, 1918, at College Station, Tex.

On March 27, 1919, at Washington, D. C., about 1½ hours before the arrival of a well-defined squall-line (wind-shift line) the festoons diagramatically shown in figure 7 were seen bulging from the base of a nimbus sheet and silhouetted against the northwestern sky. Here the process of active convection which was forming the nimbus was visible. Small festoons would grow downward, slowly trail behind in the slower-moving air below, and evaporate before being carried back to the cloud by the compensatory upward currents.



FIGS. 7 and 8.—Mammato formation on boundaries of warm currents, Washington, D. C., Mar. 27 and Feb. 28, 1919 (see fig. 2).

The formation of mammato-cumulus seems to be more common when the under current is the colder, for then convection does not set in and destroy the formation.

Gaston Tissandier [8] gives the following interesting account of observations made in a balloon ascent on August 16, 1868 (Observations Météorologiques en Ballon, p. 5):

> Two very distinct currents were superposed in the air. The lower current prevailed from the surface of the earth and the sea up to an altitude of 600 meters. It had a temperature of 13° C. It was directed from the northwest toward the southeast. At its upper part, white and flocculent clouds, isolated from each other by small intervals, were situated in the same horizontal plane in considerable numbers. They floated at the upper surface of the aerial current and in the same direction. These cumulus were rounded and mammillated; their thickness was slight, and did not exceed ten meters. The upper surface of these clouds was uniform and situated exactly in one plane. It is probable that they were arrested or dissolved by the upper current, which glided above them in an opposite direction; that is, from the southeast to the northwest. By a singular effect of perspective, this succession of mammillated clouds, viewed from an altitude of 1,600 meters, appeared to originate on one side of the horizon and disappear on the other.

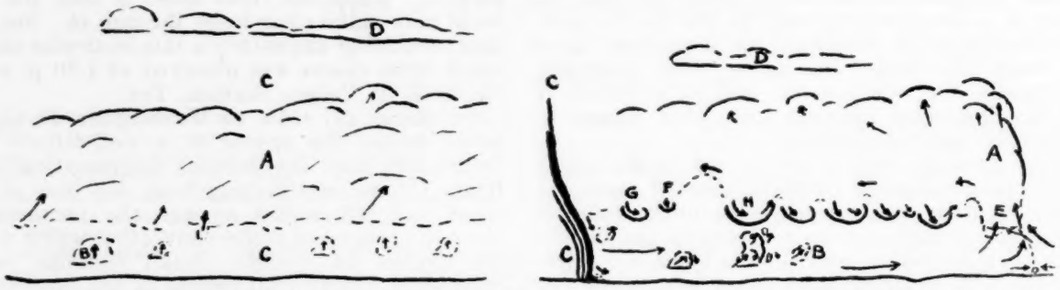
Figures 2 and 8 give some idea of the outline of the underside of a mammillated stratus sheet which covered the sky at 7 a. m., February 28, 1919, at Washington, D. C. The larger festoons would gradually bend backward (see dotted outline) as they were dragged forward from the southwest over the northeast undercurrent. The clouds did not last long, though after they had evaporated heavy alto-cumulus formed higher in the southwest wind; and rain began to fall from them at 10:30 a. m.

The most marked mammato-cumulus formation which results from a warm current overrunning a cool one is the boiling "mammillated squall cloud," illustrated in figure 3, of the plate facing page 397, and shown diagramatically front view and cross-section in figures 9 and 10. This heavy, low festoon formation is on the underside of a cumulus cloud in a belt miles long and a few miles wide. The description of the occurrence between 6:30 and 7:30 p. m., July 15, 1919, at Washington, D. C. (figs. 9 and 10), applies as well to the occurrences of October 26, 1918, on the front of a Texas "norther" at College Station, Tex., and March 27 and May 17, 1919, at Washington, D. C. The conditions July 15 were exceptionally favorable for a study of the movements involved, for the parent thunder-

* An extensive mammato-cumulus formation was observed on the under side of the A.St overflow sheet of an intense coastal cyclone, east and norteeast of Washington, at 3-4 p. m., Aug. 13, 1919.

[7] H. Osthoff has described 67 observations of mammato-cumulus, many of which may be ascribed to mixture on wind boundaries. There are numerous drawings in his article. See Met. Zeitschrift, 1906, pp. 401-408, 6 figs.

[8] From H. H. Clayton, Results of cloud observations, etc., Annals Astr. Obs. Harv. Coll., v. 30, pt. 4, p. 397.



FIGS. 9 and 10.—Lower clouds on side of thunderstorm, Washington, D. C., July 15, 1919. A, St.Cu. cloud over squall; B, Fr.St. squall cloud; C, rain front in background; D, A.Cu.; E, squall front cloud curtain; F, G, H, "mammilated squall cloud" (see fig. 3 on pl.). All arrows indicate movements seen.

storm passed on the north, and so, produced a moderate squall wind which lasted for a considerable time before rain (except occasional drops) fell at Washington. Before the squall the wind was moderate southwest, and alto-cumulus clouds were moving from the west-southwest. At about 6:30 p. m. a heavy, gray cumulus roll was seen forming in the northwest-north against a dark, rainy background. Its top was moving from the southwest. Flecks of cloud appearing just under the base rose and grew rapidly into the cumulus. Still lower were rising pieces of cloud which seemed to be beyond the cloud front, and which did not join it (see fig. 9). Just as the front edge of the heavy strato-cumulus cloud passed overhead a light air movement and then a moderate northwest wind sprang up. Just behind the low, heavy curtain-like front of the strato-cumulus (E, fig. 10) was a downward boiling sky of black-tipped great festoons and rolls (F, G, H, fig. 10). Up through ragged holes the interior of the strato-cumulus could be seen traveling from the southwest as before. A point would be seen slowly beginning to descend, then it would become a part of a small knobby festoon, which would grow downward and expand, then begin moving from the north and finally northwest, becoming overgrown and ragged. Finally, just as parts were beginning to rise again it would have broken into irregular pieces, the inside having been evaporated by the compressional heating as it descended. Here was strong mixture on a turbulent boundary where a northwest squall was driving into a southwest wind.

CONCLUSION.

Since "mammato-cumulus" clouds may be formed in such a variety of ways, a simple record of the fact of their occurrence will tell but little concerning the atmospheric processes involved except that there were either warm or cool local down-thrust currents made visible by saturated moisture.

CLOUD SHADOWS.

Mr. H. H. Martin of the Columbus office of the Weather Bureau has sent us a description of a rather unusual projection of the shadow of the top of one cumulo-nimbus cloud on the underside of the overflow top sheet of another. The accompanying line drawing by Mr. Martin illustrates the relative positions of the clouds and shows that the shadow projected was from a portion of the cloud not visible to the observer. In this respect the conditions are somewhat like those on a previous occasion when a pronounced protuberance in the top of a cumulo-nimbus cloud made its presence known by the shadow it cast.[1]

"[At about 2 p. m., July 5, 1919]. a thunderstorm was forming in the southeast. Although without northwesterly movement, this spread a curtain of alto-stratus northwestward across about three-fourths of the sky, the line of demarkation between cloud and clear sky being well defined, the sun shining brightly. At about 5:30 p. m. (90th Meridian Time) another cloud, forming in the northwest, assumed the characteristics of a thunderstorm and progressed slowly southward. Passing directly before the sun about 6 p. m., the sun's rays could be

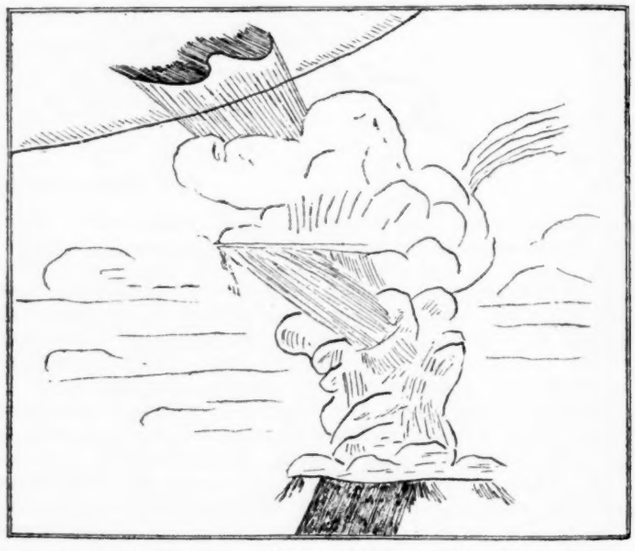


FIG. 1. Cloud shadow projection. Columbus, Ohio, July 5, 1919. (By H. H. Martin.)

seen emanating from all sides and from above. At 6:10 p. m., with the suddenness of the motion-picture projector, the cloud shadow was outlined on the cloud screen above and remained visible until 6:22 p. m."

Close observation of cloud shadows, especially when the sun is low often yields information as to form and relative heights which otherwise are not apparent.—*C. F. B.*

[1] MO. WEATHER REV., 1913, **41**: 599, fig.

MEASURING VISIBILITY.

By ALFRED H. THIESSEN, Meteorologist.

[Dated: Weather Bureau, Baltimore, Md., May 28, 1919.]

Visibility is the quality or state of being visible, and the visibility of any particular object depends in general upon the intensity of light reflected from the object toward the eye and the distance of the object from the eye.

The intensity of light varies during the day and during the year, and also varies according to the transparency of the atmosphere depending upon the presence of haze, smoke, fog, dust, rain, snow, and changes in the indices of refraction in sections of the atmosphere between the object and the observer.

This element of visibility is very important to aviators and gunners. It is important to know the visibility at night as well as by day, as aviators may desire to travel at night and even to land, and the intensity of lights at the landing field, and the efficiency of light thrown by flares depends upon the visibility.

There would, upon first consideration, seem to be very little difficulty in measuring visibility, because the observer is simply measuring how far he can see. But there are really many difficulties in the work, which will be reviewed in order.

The observers having objects located at definite intervals from the point of observation are trying to measure how far they can see. Leaving the personal equation out of consideration for the moment, they may determine either (1) the farthest object they just can see, or (2) the one that is just outside the range of vision. If they choose the first (1) method, then it is a question of how well the object should be seen, and if one should be able to see any of the details, as for instance the windows of a house.

During the late war the French used a scale of visibility which, with slight modifications, was adopted by the Meteorological Section of the United States Signal Corps.

The modified scale of visibility was:

	Kilometers
Very poor	0 to 2
Poor	2 to 5
Fair	5 to 10
Satisfactory	10 to 15
Good	15 to 20
Excellent	20 to 25

In this scale the visibility was said to be "Satisfactory" if one could see objects 10 to 15 kilometers away, and so on, with the remainder of the scale.

The above scale has been superseded (Jan. 1, 1919) by the following scale of surface visibility, adopted by the Meteorological Office of London, the Admiralty Meteorological Service, the Meteorological Service Royal Air Force, and the French Army Meteorological Service:[1]

Visibility scale.	Objects not visible in good daylight beyond—	
	Meters.	Miles.
0. Very bad	200	0.1
1. Bad	500	.3
2. Very poor	1,000	.6
3. Poor	2,000	1.2
4. Indifferent, ordinary	4,000	2.5
5. Fair	7,000	4.3
6. Good, above ordinary	12,000	7.5
7. Very good, unusual	20,000	12.4
8. Exceptionally good	30,000	18.6
9. No report (for telegraphic use)		
	Objects visible in good daylight beyond—	
10. "V" of Beaufort notation	30,000	18.6

[1] From Met. Off. Circ. 32, Feb. 1, 1919, p. 3.

In this scale the limits are carried out farther, which is certainly necessary in the lower limits of the scale, as in the case of the existence of fogs.

It has been the practice in measuring visibility to select objects found in the landscape, as barns, houses, trees, woods, lighthouses, etc., and it has been suggested that the typical objects subtend a vertical angle of 10′ and a horizontal angle of 2½′.

The practical objections to selecting objects at random are that they will differ in shape and color, do not lie in one line of sight, and do not have the same background. A white house can be seen farther than a brown house, both having the same size and shape and both being in nearly the same line of sight. The visibility of either will depend greatly upon its background. Two objects exactly alike as to size, shape, and color, but one lying to the north and the other to the south, will be visible to different degrees. Another difficulty in using objects found in the landscape is that the observers become skillful in discerning what they are looking for, and if transferred to another station, where the objects will in all probability be different, they will, at the beginning at least, make observations not comparable with those made at their previous stations.

To overcome these objections, one may have a series of specially constructed targets, each series being alike for all stations. These targets may be a white circle painted upon a dark background, or any other specially designed object which may prove best for the purpose. The series at all stations should preferably lie to the north. The individuals of a series at a station will differ only as to size, which size should be determined by the angle which they should subtend. This will probably prove expensive, and a single target may be made to serve the purpose, and in many cases may be necessary, as it is extremely difficult to arrange a series in the same line of sight on account of intervening ravines, valleys, or hills.

This single target should be placed at 200 meters from the point of observation. It may be viewed through smoked glasses having 8 degrees of transparency. The smoked glasses take the place of sections of dusty atmosphere and may be so selected that measurements made on the standard object 200 meters away will be comparable to measurements made with the naked eye on objects placed at various distances from the point of observations. For example, if object is visible to the naked eye and not through glass No. 1 the visibility is "bad." If the object can be seen with No. 6 but not with No. 7 then the visibility is "good."

Another method is to observe the target with a telescope so built that its power can be changed rapidly and as many times as there are degrees to the visibility scale. A suitable target would be one with a white background hatched with black lines. This target at a proper distance will appear gray, but if a telescope with sufficient power were used the individual lines would be discerned and the measurement would correspond to a certain degree on the visibility scale.

Observers are called upon to measure visibility at all hours of the day and night, and leaving out of consideration the transparency of the atmosphere, the intensity of light will vary from bright sunlight to the pitchy darkness of a cloudy night, and during the year from bright summertime to the darker days of winter.

In measuring visibility during the 24-hour day the following factors should be applied, owing to the variations in seeing mentioned in the preceding paragraph:

First. Angle of light rays illuminating the object or target.

Second. Condition of sky as to cloudiness, twilight starlight, and moonlight.

At nighttime visibility may be measured by observing several lights in a row, the lights to be screened by glasses having varying degrees of transparency; or a single light could be used, the observer peering through smoked glasses at the point of observation. Experiments are now being made to develop a standard visibility measurer in which a screened light is viewed through glasses of differing opaqueness.

THE AURORA OF MARCH 7-8, 1918.

By HERBERT LYMAN and CHARLES F. BROOKS.

[Dated: Weather Bureau, Washington, July 3, 1919.]

SYNOPSIS.—After discussing auroral phenomena in general, including types, latitude variation, periodicity, height, and cause, this article describes the principal features of the remarkably brilliant aurora of March 7–8, 1918, and presents a large number of detailed accounts by observers in the United States.

A chart of the United States shows places from which reports of the aurora were received. To facilitate intercomparison the descriptions have been grouped and discussed by latitude belts of 2½° each, for as would be expected, the display was pretty much the same at the same latitudes.

The aurora became visible at dusk, March 7 and attained its greatest brilliance, generally, at 9:30 p. m. (90th Meridian Time). Since no display is homogeneous, however, there are variations in the times of greatest brilliance and in the appearance of details of the display, although there is general unanimity concerning the times, colors, brilliance, and aspect, among widely scattered observers. The descriptions of the positions of arches, particularly of a prominent red one, make it obvious that the actual location of the aurora is the factor which determines its aspect, and the distance to which it can be seen, while the lack of streamers in the display at most southern points show that the clearness of the air limits its visibility.

It seems that the magnetic disturbance accompanying this aurora was a repetition, after three 27-day intervals, of the large magnetic storm of December 16–17, 1917. There was a considerable disturbance on January 12, and a minor one at the end of the next 27-day interval in February. Auroras on April 4, 5, and 6, marked the end of this strong series, which was probably caused by 5 successive presentations of an active area on the sun.

INTRODUCTION.

Auroras have always excited widespread interest not alone because of their wonderful formation and beautiful coloring but also because of their very mysteriousness. A superb example of the aurora was that which occurred on the night of March 7–8, 1918. This aurora was witnessed simultaneously over practically the entire North American continent and in Europe. In the United States auroras are not often seen south of latitude 40°, yet in this instance the phenomenon was observed as far south as Miami, Fla., where the observer described it as "a brilliant illumination of the northern sky." Aside from the unusual geographical extent of this auroral display, the most noteworthy features were its brilliance, coloring, and extent over the sky. Several observers said the light from the aurora equalled the light from the full moon. The coloring was magnificient. Various shades of red were generally observed as well as greens and the usual yellows and white.

Reports and notes on the aurora of March 7–8, 1918, received from a large number of regular and a few cooperative Weather Bureau stations, where the sky was not obscured (see fig. 1), also a few reports from observers in other parts of the world, have been assembled and tabulated in groups by latitudes.

It is hoped that these descriptions may be usable for any studies of the geographic synchronism of the times of great brilliance, and for comparisons of the times of occurrence and appearance of particular features as seen at different places. There is such a mass of detail, however, that it may be best to precede the local descriptive matter with (1) a general discussion of the aurora polaris as to its essential features and probable cause, (2) the inferred make-up of great auroral displays, and (3) a summary of the principal features of the aurora of March 7–8, 1918.

AURORA POLARIS.[1]

By W. J. HUMPHREYS.

The aurora polaris is a well-known but imperfectly understood luminous phenomenon of the upper atmosphere. * * *

Types.—While no two auroras are exactly alike, several types have been recognized, such as arcs, bands, rays, curtains or draperies, coronas, luminous patches, and diffuse glows. The arcs normal to the magnetic meridian, often, but not always, reach the horizon. Their under edge is rather sharply defined, so that by contrast the adjacent portion of the sky appears exceptionally dark. The rays, sometimes extending upward from an arch, at other times isolated, are parallel to the lines of magnetic force. Many auroras are quiescent, others exceedingly changeable, flitting from side to side like wandering searchlights, and in some cases even waving like giant tongues of flame.

Latitude variation.—The aurora of the Northern Hemisphere occurs most frequently, about 100 per year, at the latitudes 60° (over the North Atlantic and North America) to 70° (off the coast of Siberia). Its frequency appears to be less within this boundary, while with decrease of latitude it falls off so rapidly that even in southern Europe it is a rare phenomenon. At the same latitude it is distinctly more frequent in North America than in either Europe or Asia.

The distribution of auroras in the Southern Hemisphere is not so well known, but it appears to be similar, in general, to that of the northern.

Periodicity.—It is well established that on the average auroras are more numerous during years of sunspot maxima than during years of spot minima. They also appear to be more numerous before midnight than after. Relations of frequency to phase of the moon, season, etc., have also been discussed, but with no conclusive results.

Color.—Many auroras are practically white. Red, yellow, and green are also common auroral colors. Some streaks and bands are reddish through their lower (northern) portion, then yellowish, and finally greenish through the higher portions. Much of the light is due to nitrogen bands, but the source of the most prominent line of the auroral spectrum, λ .557μ (green), is not known. It has often been attributed to krypton, but other conspicuous krypton lines are absent; besides krypton is too heavy to exist at auroral heights in sufficient abundance to produce a spectrum of such brilliance.

There is good evidence that this green light, the light that produces the "auroral line," is always present in the sky, though whether wholly of auroral origin, or due in part to bombardment by meteoric dust, or to some other cause, is not known.

Height.—The problem of the height of auroras has often been investigated, but only recently solved. By simultaneously photographing the same aurora from two stations against a common background of stars, and measuring the parallax obtained, Störmer[2] and Vegard and Krogness[3] have secured many excellent height measurements. The upper limits of the auroral light vary from about 100 kilometers to over 300 kilometers; and the lower limits from perhaps 85 kilometers to 170 kilometers, with two well-defined maxima, one at 100 kilometers, the other at 106 kilometers.

[1] Quoted from "Physics of the Air," Journ. Franklin Inst., Oct., 1918, pp. 481–484.
[2] Terr. Magnet. and Atmos. Elec., 1916, 21: p. 157.
[3] Terr. Magnet. and Atmos. Elec., 1916, 21: p. 169.

Cause.—The fact that brilliant shifting auroras are accompanied by magnetic storms renders it practically certain that they, and presumably therefore all auroras, are due to electric discharges; and the further fact that they vary in frequency with the sunspot period indicates that this current either comes from or is induced by the sun. For some time it was thought probable that auroras are caused by negative particles shot off from the sun and entrapped by the magnetic field of the earth. On the other hand, Vegard[4] has given strong arguments in favor of the α particle which is positively charged, and Störmer[5] has found at least one case that required the positive charge to account for the observed magnetic disturbance.

The evidence, then, while not conclusive, indicates that auroras are due to streams of α particles in the upper atmosphere shot off by radioactive substances in the sun.*

the sun. We may assume that at such times great jets or streams of electrified matter (electrons perhaps), akin to cathode rays in a vacuum, are projected with high velocities outward, and that occasionolly some of these jets cross the earth's orbit or pass near to it, being when leaving the sun in a general radial direction, bent backward, for obvious reasons.

That electrified matter in a vacuum does move in jets or streams for indefinite distances is a fundamental fact. Moving charges of the same name in paths, straight or curved, act like parallel currents and attract one another, the more as their velocity is greater, until the static repulsion of such like charges sets a limit to further approach. It is possible that the space around the sun may be crossed by many such jets or streams of electrified matter moving at very high velocities into the vacuous space. The coronal streamers may be the visible composite effects of the projected jets. Such electrified jets may act

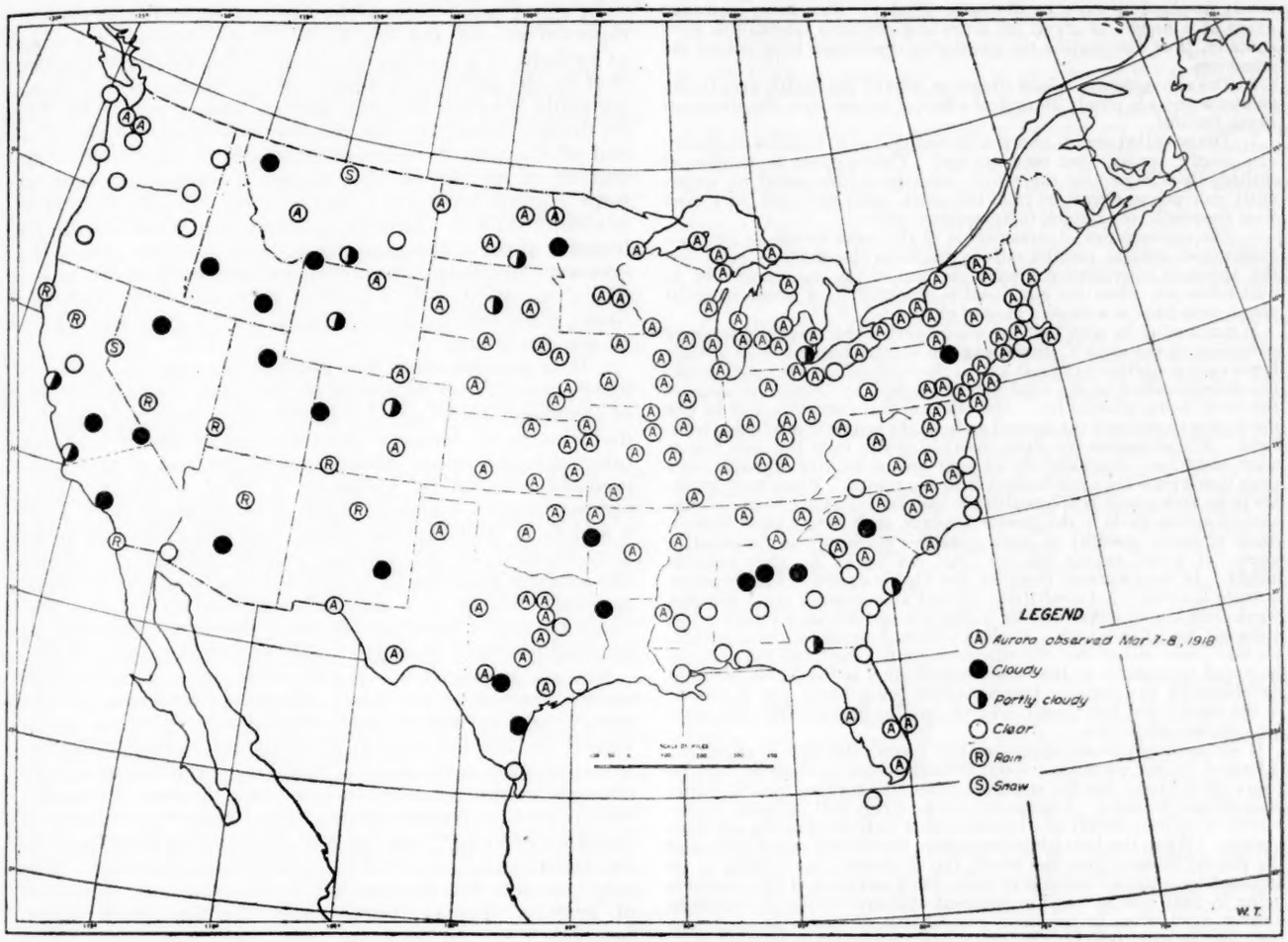


FIG. 1.—Where the aurora of Mar. 7–8, 1918, was observed.

INFERENCES CONCERNING AURORAS.

CERTAIN PHYSICAL FACTS REGARDING THEM.[6]

By ELIHU THOMSON.

It seems doubtful if any extensive auroral display has occurred without coincident existence of exceptional areas of disturbance on

inductively by proximity to the earth or directly by conduction of electricity to the earth's outer atmosphere.

In the present paper, however, it is hoped to prepare the way for further study by pointing out certain physical facts regarding the relations of auroral phenomena to the earth and its atmosphere; to locate and give direction to the streamers seen in auroras; and to explain the nature of the so-called auroral arch, the zenith crown, and other characteristics. It is believed that the following propositions may be shown to be true:

1. Streamers seen in auroras, singly or in composite masses, are in reality vertical, or approximately so, to the earth's surface, nearly parallel when adjacent, and only slightly divergent even when miles apart; the divergence being due to curvature of the earth's surface.

2. In many auroras, the streamers appear to be located in bands or zones more or less wide in latitude, extending generally in east-and-west direction, or forming belts or zones between parallels of latitude in which the streamers extend vertically upward like trees in a forest. * * * The same auroral appearances are possible to be seen alike at different places simultaneously only when a system of vertical streamers exists. * * *

[4] Phil. Mag., 1912, **23**:211.

[5] Terr. Magnet. and Atmos. Elec., 1915, **20**:1. See also, 1917, **22**:23 and 97 (abstr. Sci. Am. Supp., Mar. 30, 1918, p. 197).

* For a good, well-illustrated, popular account of the theory of the aurora, see Sci. Am. Supp., Aug. 31, 1918, pp. 132–134.

A very complete bibliographical, mathematical discussion: "Bericht uber die neueren Untersuchungen am Nordlicht," by L. Vegard seems to be the best aurora paper now in print: Jahrbuch der Radioaktivität und Elektronik, 1917, **14**:383–465, 7 figs., 5 tables. The bibliography, pp. 385–387, contains 86 titles. The titles of the five chapters are: I, "The most important characteristics of the aurora"; II, "Historical summary of the theory of the aurora"; III, "Establishment and foundation of the cosmical ray hypothesis and theory of the aurora"; IV, "The characteristics of the aurora in the light of the cosmical ray theory"; and V, "The physical nature of the cosmical rays."

[6] Quoted from Proc. Nat. Acad. Sci., Washington. (Reprinted in Sci. Am. Supp. 2151, Mar. 24, 1917, pp. 182-183.)

3. In some rare auroras the vertical streamers are closely limited to a narrow belt of latitude; sometimes only 2 or 3 degrees, or even less, in width north and south, while the east and west extent of the narrow belt may be very great.

4. In widespread auroras the belt of vertical streamers may cover great extents of latitude and extend east and west unlimited distances. This appears to have been the case in the recent great aurora of August 26, 1916.*

5. The curvature of the so-called auroral arch is an optical effect of perspective, slightly added to by the curvature of the earth. The appearance of folded curtains of streamers is a similar effect of superposition and perspective when the active band or zone covers many degrees in latitude. It is probable that the lower ends of auroral streamers have about the same height in the earth's atmosphere; a layer from which they stream upward to heights which vary in different displays or even in the same display. This layer probably exists at a height of about 50 miles and conducts laterally or horizontally, thus distributing the electricity discharged from it into the streamers.

6. The convergence of long streamers toward the zenith seen in the greater auroras is purely an optical effect of perspective, the streamers being vertical.

7. The so-called zenith crown is in reality due to bundles of streamers, nearly vertical but seen on end. They appear as patches of shifting light in or near the zenith, sometimes surrounded by apparently converging streamers from the north, east, and west, and even from the south; converging in appearance only.

8. The convergence of streamers is of the same nature as the convergence of straight parallel railway tracks in the distance, or better, the apparent convergence toward the sun of the sunbeams seen in dust-laden air, when the sun itself is obscured by a small irregular cloud, or is back of a broken mass of clouds. * * *

It can readily be seen that the recognition of the vertical relation of streamers to the earth's surface and the nearly constant level of their lower ends simplifies to a great extent the study of auroras, particularly the determination of the total height reached by them, curvature of the earth being allowed for. The effect of this curvature will be less the higher in altitude the auroral arch, or the nearer it is to being overhead. The streamers are often observed to rise from the arch first as short streamers, gradually developing and extending upward until their upper ends are a few degrees from the zenith. When they originate in an arch which is of low altitude and extend nearly to the zenith, as they appear to do in the greater displays, their length must be hundreds of miles, possibly in some instances reaching one thousand or more. It would appear that no limit can be set for their possible height. In most auroras, however, the visible extent of the streamers is more limited. A low-altitude auroral arch implies great distance north from the observer and for a given actual streamer length a less apparent height or length. Paulsen's class of auroras without streamers may mean either that the streamers are too short and too many to be noted separately, or that the electrification is too feeble for their development, the observed luminous glow being due to flow of current in the conducting layer itself, an arch forming horizontally, but without outward projection.

If our assumptions are approximately correct the arch of an aurora, if located farther north than about 600 miles from an observer, will be below his horizon, but the streamers extending upward from it if long enough may be seen. Auroras far north of this will probably be invisible or be seen merely as a luminous glow well down on the northern horizon. When the breadth in latitude of the auroral zone is great and the display is seen from the south, the streamers may overlap or be arranged in apparent curtains or folds, the lower ends of the streamers being in that case at varying apparent altitudes above the northern horizon even when in the same general line of view. In such case they may be superposed in the line of sight and therefore be composite, or increased in apparent length owing to imperfect superposition in their lengths with respect to those back or front of them. It is believed that these and like considerations will suffice for the explanation of observed appearances of auroras in spite of their great variety.

* See MO. WEA. REV., 1916, 44:440-444; also Science, N. Y., 1916, N. S. 44:717-722; and Sci. Abs., 1917, 553.

PRINCIPAL FEATURES OF THE AURORA OF MARCH 7–8, 1918.

Time of occurrence.—Since the aurora is generally considered to be the result of the arrival of clouds of particles, or special "rays," from the sun, important variations in brilliance should be noted almost simultaneously over the whole earth wherever the display is seen. This brilliant March aurora attracted much attention because it coincided with an air raid upon London. "The northern sky was lighted up with a crimson glow both before and during the raid, which started shortly after 11 p. m.[7]

A magnetic storm of no great duration, but very considerable amplitude, was recorded at the Eskdalemuir, Kew, and Agincourt (Ontario) Observatories on the night of March 7–8, 1918. It began with 'a sudden commencement' at about 9h. 10m. p. m., on March 7. The largest movements occurred in the early morning of March 8, between 1 and 5 a. m., but smaller oscillations persisted for some time after the latter hour.

In the United States the earliest auroral observation reported was 0h. the 8th, G. M. T., the display appearing at twilight at a number of places. The maximum phase, that is, the greatest brilliance of the aurora was reached generally between 3h. 30m. and 3h. 40m. a. m. (G. M. T.); for hours, however, the display was exceptional. The end of the aurora occurred generally between 4h. 30m. and 5h. a. m. (G. M. T.), though a revival was seen at some sations between 7 and 8 a. m. (G. M. T). It is evident that the aurora was coincident with the major features of the accompanying magnetic storm.[8] Since the greatest magnetic disturbances occurred between 1 and 5 a. m. (G. M. T.) (7 to 11 p. m., 90th meridian time), observers in North America were the most likely to see the aurora.

"It is possible that the disturbance was a repetition after three 27-day intervals of the large magnetic storm of December 16–17, 1917. There was a very considerable disturbance on January 12 at the end of the first 27-day interval and a minor disturbance at the end of the intermediate interval in February."[7] The brilliant, partly crimson aurora observed April 5 (with lesser ones April 4 and 6, in New Haven, Conn., and elsewhere) seems to have marked the last, intense, periodic recurrence. Since the synodic rotation period of the sun is about 27 days, it seems that on five successive presentations of a particularly active area on the sun, the earth received an unusual quantity of magnetically disturbing emanations.

General appearance.—While there is a general unanimity concerning the time, colors, and brilliance of this aurora among widely scattered observers, there is an almost endless amount of differing detail in the descriptions of the appearance, brilliance, movements, and changes in the positions of important factors of the display. In the nature of the case, since the clouds of electrons arriving from the sun could not be homogeneous the aurora must be streaky or spotted in character. This may account for the inexact synchronism of the times of brighter display, particularly the maximum phase, between 9:30 and 10 p. m. (90th meridian time). How a given bright portion will look must depend largely on the location of the observer. Since the altitude of the aurora is generally more than 90 km., particular features of display should be visible at the same time from widely separated localities.* The actual location of the aurora is thus the limiting factor in the distance to which it can be seen; and the clearness of the air determines its visibility within the possible limits.

[7] Quotations from Nature, Mar. 14, 1918, p. 32. (Repr. in Science, Apr. 12, 1918, p. 359.)

[8] The closeness of the interrelation between this aurora and the magnetic storm is well brought out by a comparison of the descriptions that follow, with Dr. D. Chree's article, "Magnetic Storm, of March 7-8 and August 15-16, 1918, and their discussion." Proc. Roy. Soc., Ser. A, vol. 96, pp. 32-55, Aug. 1, 1919.

* Cf. E. Loomis: A Treatise on Meteorology, N. Y., 1899 edition, pp. 173-201. This is a very complete illustrated description of the aurora.

See also Cl. Abbe's articles, "Altitude of the aurora above the earth's surface;" Terr. Mag., 1898, 3: 5-12, 53-76, 149-178.

LOCAL ACCOUNTS OF THE AURORA OF MARCH 8, 1918, BY LATITUDE BELTS.

The reported observations have been grouped by latitude belts of 2½° each, for, as would be expected, the display had some uniformity within each latitude belt. Comparisons of accounts from nearby stations in different latitudes are also interesting. Much of the information found in the reports collected from the localities from which descriptions have been received has been included in the discussions by latitude belts, so those notes mentioning the fact of the occurrence of the aurora and perhaps a few general features of the display have been omitted, while all the extensive detailed descriptions, and a few others, in all, have been quoted below.

52½ to 50° N. lat.—The following extract is from the account by Mr. F. W. Venables, Observer at South-end-on-Sea. It is exceptional for the aurora to produce such striking effects in the south of England.

Just after one o'clock I went out into the street to have a look round and saw a neighbour, who said he had been watching a red glow in the sky as though there was a fire; the direction he pointed out to me was NE.

As we stood talking a strange light seemed to appear as though the moon was rising; we commented on this and said it could not be the case as the moon did not rise till after 3. We then noticed it appeared brighter across the fields looking due N.; the sky at the time was perfectly clear of clouds; the colour of light appeared a light greenish tint on the horizon, which then changed into a turquoise a trifle higher in the sky, then into a pink tint and lastly at the highest point it was a rosy hue; the colours were then magnificent from the horizon to about one-third up the sky, and remained so for nearly ten minutes, from 1:20 to 1:30; the position of light was from N. to NNW.—*Met. Off. Cir., 22, Mar. 26, 1918, p. 3.*

50° to 47½° N. lat.—In this northern belt, for which observations from four places are at hand, the display at its greatest extent covered practically the entire sky. There was, naturally, no well-defined arch, and the aurora seemed to have little unity as a display, except perhaps for the unusual amount of red coloring.

Devils Lake, N. Dak. (90th meridian time), *March 7.*—The auroral display on the 7th was brilliant and magnificent and prevailed from 7:45 p. m. to 11 p. m. There was no well-defined arch. Many streamers of light and patches of light were prevalent in all regions of the sky, being especially prominent in the northeast and northwest sectors. The beauty of this display lay in its peculiar colors, of which the reddish tints were the most prominent. It was like the reflection in the sky of numerous distant conflagrations.

Williston, N. Dak. (90th meridian time), *March 7.*—An aurora was observed at 9:40 p. m., which extended in azimuth from 125° to 270°, and gradually extended to 300°. When first observed streamers which were of any ashy color reached almost to the zenith, but by 10:05 p. m. had moved southward, passing through the constellations of "Orion" and "Taurus"; about 10:10 p. m. the streamers had increased in density, at times resembling cirrus clouds; from 10:15 to 10:30 p. m. the streamers along the zenith for about 25° were tinted a light pink, which changed gradually to a fairly bright rose color; after 10:30 p. m. the streamers began to disappear, and by 10:45 p. m. the aurora was no longer visible.

Port Angeles, Wash. (120th meridian time), March 7.—Aurora observed on the night of the 7th, fairly bright, no streamers, only a glow.

47½° to 45° N. lat.—The nine reporting stations in this belt indicate that here also the aurora had a very indefinite form. The whole sky, except for less than 30° above the southern horizon was covered by the display. At a few places the principal display was in the south. The light was described as brilliant; and reds, white, greens, and yellows were the predominating colors. The tremulous motion visible in intense displays was mentioned in one report. In upper Michigan, at least, wire communication was rendered difficult. Where observed late, the display prevailed throughout the greater portion of the night.

Alpena, Mich. (90th meridian time), *March 7.*—The auroral display of the 7th was first observed at 7:10 p. m. as a diffused glow of straw-colored light in the southern sky. At this time the clouds were dissipating rapidly and soon revealed the fact that the entire heavens were brilliantly illuminated with a steady glow. Beyond [?] this glow a band of rose-colored light extended from east to west through the zenith. This band slowly faded overhead and broadened in the eastern and western skies. Later the straw-colored glow broke up into streamers and fiber-like clouds with the lines converging at a point slightly south of the zenith, forming a dome-like structure. At this time the luminous beams assumed a tremulous motion, producing a magnificent effect in front [?] of the rose-colored background. The whole display was characterized by the fact that it covered the whole heavens, starting close to the horizon. It disappeared at 11:15 p. m.

Escanaba, Mich. (90th meridian time), *March 7.*—An aurora was observed on this date from 6:45 p. m. until 11 p. m. The aurora consisted of two well-defined arches, the largest one extending from about 100° to 360° in azimuth, with an altitude of 45°. The second and subordinate arch had dimensions of about 120° to 200° in azimuth, with its arch of 20° in altitude. In appearance and general composition this aurora was the most beautiful of any ever observed at this station, surpassing that of August, 1916. As the phenomenon gradually increased in magnitude, bright streamers were seen to be concentrated at the zenith. These streamers were observed to be of bright yellowish light. After a short interval the scene and color changed to the eastward, where the streamers converged and outlined a well-defined circle resembling a halo of great proportions. The outlines of this circle gradually faded away and again the scene changed. The streamers turned to a pale alto-stratus cloud-like form, and, intermingled in this, appeared luminous bright red, fiery lights. Then greenish colors appeared and mingled with this red, the whole moving in a straight path from northwest to southeast. As the masses moved across the sky, they seemed to be attracted to the zenith, presenting the appearance of a huge parasol and covering the zenith for a large area around. The aurora prevailed throughout the greater portion of the night.

Houghton, Mich. (90th meridian time), *March 7.*—A brilliant aurora was observed on the 7th from 9 p. m. to midnight. It consisted of rapidly changing and many colored luminous patches, streamers, and flashes of light, at times being most brilliant in the south. Telegraph and telephone communication was rendered very difficult most of the night.

Sault Ste. Marie (90th meridian time), *March 7–8.*—An aurora of great brilliancy and unusual color and formation was visible from 9 p. m. to 11:30 p. m. on the 7th. It formed a complete circle, at no point approaching the horizon nearer than 35°. From 60° to 110° streamers started about 60° above the horizon. The predominating colors were white and green, with occasional patches of red, which varied from light to very dark. The red patches appeared on all sides, except north, shifting from point to point, appearing at times pale and gradually becoming very dark, later fading and almost disappearing. At 9:40 p. m. red was the predominating color directly overhead, with very dark patches on the easterly and westerly quadrants and lighter on the southern, with greenish white streamers between and faintly discernible through [?] them.

Duluth, Minn. (90th meridian time), *March 7.*—The aurora on the 7th was unusually brilliant. It was first observed at 8:15 p. m. and consisted of innumerable shafts of dazzling white, areas of pink and light to dark green color in rapid and rather bewildering sequence. The display continued with varying brilliancy until about 11 p. m. after which it was confined to widely scattered sections of the sky. At 9:30 p. m. the display centered at the zenith with pink and white shafts radiating therefrom in all directions, most of these shafts reaching nearly to the horizon.

**Northfield, Minn.*—The display was on when twilight darkened and was still active at 10:45 when our watch upon it ceased. A great green arch extended from the western horizon at azimuth 100° to the eastern horizon at azimuth 280°, passing over the constellation Orion in its course. The arch was wide enough to more than cover Orion. It drifted slowly southward until the lower edge covered Sirius. A narrower arch of the same color occasionally formed and disappeared about midway between the great arch and the southern horizon. Above the great arch was another arch of changeable color, red, yellow, and greenish white, composed of nearly vertical streamers, converging by perspective toward a point 5° to 10° south of the zenith. This arch was very bright red, especially toward the west in azimuth 105°, where it persisted during nearly the whole of the hour from 7:15 to 8:15, after which clouds intervened for a time. During part of the time this arch passed over the Pleiades and Castor and Pollux. Toward the north the auroral display was less brilliant, but there was a low green arch and many comparatively narrow streamers of red and yellowish color converging toward the zenith.

At 9 p. m., when the clouds partially cleared away, the red display had ceased and the green was less active, although it covered a large part of the sky. About 9:35 the red display again became active, but was mostly in the northern half of the sky. The great green arch in the southern sky broke up and almost completely vanished. Later the whole northern half of the sky was filled with streamers, mostly green, converging toward a point 10° south of the zenith.

* Reprinted from Popular Astronomy, No. 254, April, 1918, pp. 277–278.

A 60°-prism telescope was turned upon the bright green arch and showed the auroral line as very strong, with four fainter lines almost equidistant from each other, the fourth being near the position of the F hydrogen line. The line at E was invisible or exceedingly faint. When the spectroscope was turned on a very bright red streamer one line could be seen in the red, not far from the C line of hydrogen. My impression was that this line was farther than C from the aurora line, but I had no means of measurement at hand. At times I thought I glimpsed a line in the yellow also, but I could not be sure of this.

As such auroral displays are usually associated with extraordinary activity in the sunspots, we took advantage of the next clear day to examine the sun's surface. On March 11, the first opportunity after March 7, a large group of spots was noticed near the central meridian of the sun on the northern hemisphere. The group was approximately 100,000 miles long and the chief spot nearly 20,000 miles in diameter, showing evidences of violent internal motions.—*H. C. Wilson.*

Bismarck, N. Dak. (90th meridian time), *March 7.*—An unusual auroral display in the southern sky was observed from 8:10 p. m. to 9 p. m. During this time there was a bank of dense clouds extending along the southern horizon to an altitude of about 15°. Above this bank of clouds was an arch of auroral light extending to an altitude of about 45°. The extremities of the arch were not clearly defined on account of the presence of the clouds. Also a band of irregular width, from 1 to 5°, extended from azimuth 112° across the sky to azimuth 292°. At times streamers would radiate from the middle point of this band, about 5° south of the zenith, occasionally in all directions, but mostly in arcs of 15 to 30° adjacent to the band. The colors of the streamers and band varied from white to pink. There was no indication of auroral light in the northern sky at this time, but a northern aurora was reported as seen between 10 and 11 p. m. the same evening.

Helena, Mont. (105th meridian time), *March 7.*—An unusually brilliant aurora was observed on the 7th. It was first observed at 7:50 p. m. and continued till 11 p. m. when no further attempt was made to observe it. The arc was indistinct and the exact position could not be determined on account of cirrus clouds that covered the northern half of the sky. The light was a pale green and very bright and the northern sky looked as if there was a great fire reflected from some distant point and the sky was especially bright in the northwest, which was probably due to a less amount of clouds in that section. The light appeared to be steady and the usual pulsations were not observed.

45° to 42½° N. lat.—The 33 reports from this latitude belt indicate that the aurora was most brilliant here. Some observers described the lights as equal to two-thirds to fully as bright as full moonlight. All the sky except for a small dark segment in the south was covered by the display. Reds were mentioned at all stations, greens at most, whites and yellows at a great many, purples and blues at a few, and even the colors of the rainbow at one. Flashing, pulsating, or quivering streamers were observed everywhere, and at some points the curtain-like waves characteristic of intense auroral arches seen at a high angle. The display lasted from dusk till several hours after midnight. Telegraphic communication was reported as hindered.

Burlington, Vt. (75th meridian time), *March 7-8.*—Aurora was first observed at 8 p. m., in the form of streamers of red, green, and yellow, changing color frequently, azimuth 90° to 280°, altitude 90°. At 10:30 p. m. bright auroral corona had formed. At 11:30 p. m. the corona began fading out. The display ended during the night. It was unusually brilliant.

Buffalo, N. Y. (75th meridian time), *March 7.*—On Thursday, the 7th, an aurora was observed at 7:45 p. m. A red arch extended upward from about 135° of azimuth to about 70° in altitude and curved back to the horizon at about 225° of azimuth. White streamers extended from the north point of the horizon toward the zenith, reaching up to the red arch, and green and blue streamers from the north point to the red arch westerly from the zenith. By 8:30 p. m. the coloring had disappeared and the white streamers and band had become very faint. At 9 p. m. the aurora was no longer visible.

Canton, N. Y. (75th meridian time), *March 7.*—Brilliant display of aurora from 7 p. m. to 11:30 p. m. Entire sky covered at times with diffused light of more than ordinary brilliancy, making light at times equal to two-thirds full moon. A variety of colors ranging from green to purple and carmine made an unusual sight. Pronounced arch in the south 9 to 10:20 p. m., with streamers reaching exactly to the zenith from the arch. Very dark inside the arch.

Oswego, N. Y. (75th meridian time), *March 7.*—An auroral light was visible at 7:30 p. m. It consisted of an arch of about 15° altitude extending from northwest to nearly east, and there were several scattered beams of light of a greenish tint. At 8:10 p. m. greenish beams of light extended from the horizon to the zenith, and from west to east. The display was greatly interfered with by clouds which were moving rapidly from the west, and at 8:13 p. m. they shut out the light entirely. At 10 p. m. the aurora was again visible in the south and west. In the south it was a diffused white light extending nearly to the zenith, and from west to east. In the west there were a few streamers. Up to this hour there was very little if any motion to the beams of light. * * * The time of greatest brilliancy was from 10:30 p. m. to 11 p. m., when wide beams of highly colored reddish and pinkish light extended from all quarters of the horizon to the zenith, giving the sky much the same appearance as the reflection from a large fire. At 1:30 a. m. the light had all faded out.

Grand Rapids, Mich. (90th meridian time), *March 7.*—A brilliant auroral display was observed on the 7th from 9 p. m. till near midnight. Red, pink, and green colors predominated, and the beams traveled rapidly in curtain-like waves from west to east and attained an altitude of 90°. Azimuth 135° to 225°.

Lansing, Mich. (90th meridian time), *March 7.*—An unusually brilliant aurora borealis occurred in the night of March 7, between 7:30 and 10:30 o'clock. The display began with luminous bands across the sky, from west to east. These increased in brilliancy and a faint reddish color began to be apparent, in a band extending upward from the western horizon, about half way to the zenith and about 10° in width. This band became more brightly colored, and others soon appeared. By 9 p. m. the entire sky, except a small arc near the southern horizon, was filled with luminous clouds, and by 9.30 p. m. these had taken on many brilliant colors, deep red predominating. The heavens seemed to be covered by a canopy of film in the form of bands and streamers, converging near the zenith, and variously and brilliantly colored. After 9:30 p. m. the coloring gradually faded and the bands and streamers slowly disappeared. The whole display was awe inspiring and many people were frightened by it.

Ludington, Mich. (90th meridian time), *March 7.*—A very remarkable aurora began at about 6:30 p. m., with a whitish arch in the north whose altitude of summit was 25° and azimuth of extremities 160° and 220°, and with whitish streamers reaching from near the horizon at places all along the north through the arch and up 60° or more. The streamers moved toward the west. Near each extremity and slightly above, was a patch of reddish light. The red increased and at 7:15 it was all along the arch. The arch in the north gradually rose and probably passed overhead: by 7:40 p. m. it was in the south, with altitude of summit 30° and azimuth of extremities 100° and 270°. By this time patches and streamers were over most of the sky. In the northeast and also in the northwest was a large patch of red. The arch continued in the south until about 9 p. m. and was whitish and 5° to 10° in width. At 8:55 p. m. there were great whitish sheets, mostly in the southeast. From about 8 p. m. to late in the night a crown or center was observed overhead and slightly southeast of the zenith. At 9:35 p. m. a great dome or canopy covered somewhat irregularly almost the whole sky. The crown was just southeast of the zenith, as stated above, and great sheets and streaks of white and red diverged in all directions. Reaching to 30° west of the zenith was a large area of flaming red. There was red also in the east but farther down in the sky. The display at this time was brilliant and impressive. Long streamers were present most of the evening and drifted toward the west. Practically no flashing was observed at any time. The display diminished after 10 p. m. and disappeared by about midnight.

Saginaw, Mich. (90th meridian time), *March 7.*—A magnificent display of aurora borealis was visible at 9:30 p. m. From a point of a few degrees south of the zenith, widening rays extended in all directions, reaching to the horizon on the east, west, and north, but being comparatively short toward the south. The rays were mostly of greenish tint, with some yellowish and purple, while broad bands or patches of blood red appeared in the east and west at about 45° elevation. Near the northern horizon the sky was a deep sea-green color. The display waxed and waned for a few minutes, but the red color had mostly disappeared by 9:50 p. m. while the green was also fading. Although the beauty of the color soon disappeared, rays of white or a very pale green continued to radiate from the focal point until after 10 p. m.

Citizens reported the aurora again visible between 1 and 3 a. m. on the 8th, but not so brilliant as on the previous evening.

La Crosse, Wis. (90th meridian time), *March 7-8.*—A brilliant display of aurora was observed on the 7th, and continuing into early a. m. of the 8th. Deep red and bright green colors were noted "for the first time in this vicinity."

**La Crosse, Wis.* (State Normal School), *March 7.*—On the evening of March 7 there occurred at La Crosse, Wis., the finest display of northern lights that the writer has ever seen here. There seems to be no record or remembrance of any equal display. The lights were observed more or less from 7:30 till 12 p. m. The best were seen from 9:45 to 10:45 p. m. During this time shafts of light starting from the horizon would shoot to the zenith. These shafts would be in the north, northeast, or northwest. After these started, others would follow them till three-fourths of the heavens were covered with these shafts of light, for they extended south of west and south of east. In the parts of the heavens

* Reprinted from Science, Mar. 29, 1919, pp. 314-315.

farthest south the shafts of light were broken just below the zenith, but in the other parts of the heavens the shafts were continuous from the horizon to the zenith. The shafts did not flicker or flash as observed at other times, but remained stationary for a period and then died out.

The most remarkable thing was the colors exhibited. After the shafts had been established faint tinges of red appeared, which became brighter, till the heavens from the northwest to the northeast and for three-fourths of the way from the horizon to the zenith were covered with a bright crimson-red glow. The scene was magnificent and never to be forgotten.

The above light forms would stay for some minutes and then they would all die away and leave only a greenish hue in the north. In a few minutes more all would be repeated again. This repetition was noted several times in succession, till about 10:45 when it all faded into the greenish hue, which lasted an hour.

Other colors were observed as yellows and purples. These were seen as faint light toward the zenith, but the prominent color was the red, which with the definitely formed shafts gave a special character to these northern lights which will be easily remembered by the observers.—*G. H. Bretnall.*

Madison, Wis., March 7-8.—A remarkably brilliant aurora borealis [occurred] on the night of March 7–8, 1918. The illumination of the sky was noted as soon as twilight had passed away, and had not ended at half an hour after midnight. The most notable features were the brightness of the red green coloring, the extent of the illumination, which covered the entire sky, and the intensity of the earth-current disturbances attending the phenomenon. * * *

The illumination was brightest overhead, on account of the clearness of the sky there, but stripes and "clouds" were observed quite as far to the south as it was possible to make them out, certainly within 10° of the southern horizon.

The "radiant" of the auroral rays was about 5° south of the zenith, as judged by the eye.

The earth currents were especially strong at 7:12, 7:25, 7:31, 7:42, and 7:45 p. m., 90 meridian time. At these times they were strong enough to "arc" across the operator's keys and put a stop to telegraphic communication.—*E. R. Miller.*

Charles City, Iowa (90th meridian time), *March 7.*—Aruora was first observed at 6:40 p. m. There was then a dimly defined dark arch, the ends on horizon at 130° and 290° azimuth, the apex about 45° altitude; 40° to 45° of the sky above the arch was suffused in white, green, and yellow, while from the western end of the arch a slender rose-colored plume rose to within 10° of the zenith. It was the brilliancy of this streamer that first attracted attention to the display. At 7:15 p. m. the arch was plain, and from it extended upward quivering rose and white streamers, those from the center reaching the zenith. Between the white and rose there were broad bands of green with narrow yellow and violet edges. This formation soon broke into blotches or fields of white or rose on a green background. At one time the entire Great Dipper was enveloped in rose, the stars shining through it with undiminished brightness, with shafts of white separated by streaks of violet and yellow standing out southward, apparently horizontal. At 9:58 p. m. the arch was low on the horizon and dim, above it to zenith were broad, pale, white, green, and yellow streaks. Suddenly the base of energy shifted from the arch to overhead. Immediately around zenith lumps of white formed around a circle of blue sky some 10° radius, and having a bright star in its center. From this whitish ring streamers shot outward and downward in all directions, those to between 130° and 270° azimuth connecting with the arch, those to the southward ending when about 45° above the horizon. The streamers were of rose, violet, gray, and yellow, and stood out under a green sky filled with twinkling stars. One striking feature of the display was that no matter how deep or brilliant the intervening colors were the stars shone through undimmed. This formation remained intact for several minutes, then broke into groups of coloring which gradually faded. The display ended about 11 p. m.

Dubuque, Iowa (90th meridian time), *March 7.*—The aurora borealis on the evening of the 7th was one of the finest ever observed at Dubuque, even surpassing in grandeur the wonderful aurora of August 26, 1916.

The aurora was first observed at 7:15 p. m., consisting at that hour of a broad glow or band of light extending across the northern sky from northeast to northwest and high in the heavens. The aurora increased in brilliancy as the evening progressed, and was at its best between 9 and 10 p. m. At 9:30 p. m. the entire sky (except close to the horizon) was filled with quivering streamers or waves of light, converging overhead at a central point about 5° to 10° south of the zenith. The streamers were well defined, as though coming from searchlights.

The most distinctive feature of the aurora was the colors, green and red predominating. At 9:45 p. m. the greater portion of the northwestern sky was a brilliant red, which changed to greenish by 10 o'clock. At 10 o'clock a bright red streamer came out of the east (slightly north of east) and in a few minutes broadened out toward the north, and by 10:15 covered the greater portion of the northeastern sky. By 10:30 p. m. the northwestern sky had changed to greenish, and red appeared again in the northwest and overhead, but not so vivid as before. Perhaps the best description that can be given of the colors is that large bands or patches of red and green moved about over the northern half of the sky for nearly two hours.

Another prominent feature of the aurora was the many distinct patches or groups of light, resembling thin whitish clouds. They were numerous overhead and looked like cirro-stratus clouds of irregular shape. There was a decided contrast between the clear sky and the cloudlike patches. Where there were no patches the stars shown with much brilliancy, but through the cloudlike patches the stars shone only faintly.

A Dubuquer who spent his early life in Norway said of this aurora: "It was the finest I have ever seen in America, and resembled the wonderful auroras I used to see in Norway, except that the arch in the north was inconspicuous."

Sheridan, Wyo. (105th meridian time), *March 7.*—Brilliant aurora borealis observed early on the evening of the 7th. The first observation was at 7:40 p. m. local time, in the northwest where a fire-red sheet about 5° wide extended upward to 45° or 50° altitude. This was followed in a few minutes by a shaft of white not so broad, but reaching a higher altitude and located near a point nearly due west. Shortly after the display of red ceased in the northwest the eastern sky became red, the depth of color varying from minute to minute. At times half of the northeastern sky was red, the appearance at times being that of reflections from a huge fire on the earth. But the shifting of the sheet, its advance and retreats with the appearance of streamers of white within the red and at the border, gave proof of auroral display. At 8 p. m. a shaft of white 15° to 20° long and about 5° wide, was visible for a few minutes due east. Then the red with streamers shooting upward near to the zenith appeared across the most of the northern sky. No observations were made later than 9:15 p. m., but observers on the mountains report displays up to midnight.

Crow Hill, Wyo.—A few minutes past 7 p. m. a wierd-unearthly light appeared over the entire heavens, illuminating the evening sky; simultaneously shafts of lights began to display to within 20° of zenith, over the entire space between northwest and northeast. The display was a deep red. The line of coloring was very marked and did not merge with the other light at all. The auroral clouds moved very rapidly toward the northwest. At 7:30 p. m. the clouds diffused into continuous light, covering the entire sky, except a semicircle about 45° diameter in the south at the horizon. This continued till 8 p. m. when the red light suddenly changed into ordinary light, and the display began to wane. At 8:45 p. m. the display shifted to a position, from northeast to about 10° north of east, and the south half of the illumination was red. The illumination varied in intensity till 9:30 p. m. when I retired.—*C. A. Hurlbutt.*

Huron, S. Dak. (90th meridian time), *March 7.*—A brilliant auroral display was observed during the evening of March 7. Soon after sunset, and while the sky was still quite light in the west, it was observed that the light was not fading naturally from the eastern sky, but that there was a flare of whitish light extending up toward the zenith from a position a few degrees above the horizon a little south of due east. Soon after, a red arc of light began to appear extending up from a little south of the northwestern horizon and reaching almost to the zenith. This western red arc was at first narrow, less than a degree, and consisted of bands of dull-brick red light which at first lay quite parallel with the arc but later, 7:45 p. m., when a complete arc was formed with an apex in a crown of whitish light a degree or so south of the zenith, these red bands, which were more or less parallel, veered so as to cross the arc at an angle of about 45° extending from north to south. At 7:45 the arc was complete; the western portion being narrow, more or less well defined, and crossed by brick-red bands of light; the eastern portion being broader and composed of white light that ballooned out toward the south several degrees in places; the crown being a patch of white light a little south of the zenith, where the east and west arcs joined. The sky to the south of the arc for several degrees appeared covered with a thin high cloud that was lit up in an irregular manner and reflected light from the arc; stars were visible through this, but only the brighter stars were visible through the arc itself. The landscape was lighted with a dull reflection as from a distant fire. The north edge of the arc was quite well defined and the sky beyond dark and clear of clouds; the stars of the great dipper showed brilliantly, a bright star in the east, probably a planet, was also in this dark area. At 7:55 p. m. several sharp narrow bands appeared radiating from the north in the dark portion of the sky west of the great dipper; by 8 p. m. they had faded away. From 7:55 p. m. to 8:12 p. m. the whole arc increased in brightness, and the eastern half took on more of the appearance of the western half. At 8:03 p. m. a curtain of light appeared to radiate from the crown of the arc slowly to the northward, reaching the nearer stars of the great dipper at 8:12 p. m. Looking up at the crown of the arc the impression was that a curtain of light was unfolding and dropping from a great distance toward the observer. From 8:12 to 8:15 the light diminished; from 8:15 to 8:20 it increased again somewhat, and remained about the same until the whole phenomena was obscured by clouds that moved in from the northwest about 8:45 p. m. Later, about

10 p. m., it was noticed that the northern sky had a lumpy red appearance as though red light were being reflected from strato-cumulus clouds.

Rapid City, S. Dak., March 7.—An auroral display of unusual brilliancy and beauty was observed on the 7th. It was first seen at 7:20 p. m. (local time) and appeared in the west as a red light that resembled a large fire. Azimuth 80° to 130°. This light shown red to an altitude of approximately 40°. At about 8 p. m. the light in the west grew dim and an exceptionally fine exhibition appeared in the north, beginning at 130° azimuth and extending to 220°. This display presented the usual streamers shooting upward from the horizon, which ranged in altitude from 45° at the ends to 60° in the center. No bands or well-defined arch were seen. The light was red near the horizon and the streamers presented a reddish-yellow appearance. The phenomenon disappeared at about 10 p. m.

42½° to 40° N. lat.—The 34 reports from this belt indicate that, for part of the display, it was south of the zone of maximum, for most of the display was in the northern half of the sky, although at some places the southern auroral arch reached down more than half way from the zenith to the southern horizon. The intensity of the light is described as nearly equal to that of the full moon; and the colors were various shades of red, white, greens, yellows, blue, purples, and even orange—all together, the essential prismatic colors. The brilliant streamers flamed, pulsated, flickered or waved for brief periods, at least, at most places. The aurora was seen first at dusk, and last, at some stations in the early hours of the following morning. Wire communication difficulties were mentioned locally.

*New Bedford, Mass.**—At 10:30, when the activity was at its height, the entire northern sky was ablaze with greenish white light with countless streamers continuously darting up toward the zenith, the light being almost as bright as moonlight. * * * The entire heavens, with the exception of a space of about 30° from the southern horizon, was covered with a luminous cloud-like formation very similar to the familiar "mare's tails" except that they were constantly changing form, appearing and disappearing, streaks from north, south, east, and west converging in one small spot a little south of the zenith in the constellation Leo, just east of the Sickle. Very gradually, while all this was at its height, a faint orange red (in some places pinkish) glow appeared, arching the entire heavens from east to west. This glow slowly deepened in color, advancing from light red successively through vermilion and crimson of different intensity in different parts of the sky, until it vanished in about half an hour's time as a very deep purple barely distinguishable from the ordinary color of the night sky. All through this beautiful glow the greenish light constantly waved and shimmered like a silk flag blown out by the breeze. The peculiar part of the display was that at the north, where the greenish light was the most vivid, there was not the faintest trace of the red glow, that not commencing until an altitude of 60° or more was reached, while it descended all the way to the horizon in the east and west.—*Vincent Francis.*

Harrisburg, Pa. (75th meridian time), *March 7.*—At about 7:30 p. m. there appeared slightly east of north a very luminous, whitish segment extending from the horizon to about 30° altitude. In form it resembled a sunrise, but the brighter illumination appeared at the outer edge of the arc rather than at the apparent center of the segment. At 7:45 p. m. around the illuminated segment there appeared beams of light apparently emanating from the outer edge at an altitudinal angle of about 60°. These beams of light traveled in an east-wester direction, vanishing in the west. The beams of light were followed by red shoots or rays, which also traveled in an east-west direction. These red rays variegated into the prismatic colors for a few seconds and then blended into red. The red rays continued until about 8:10 p. m., after which there remained a whitish arc which rose gradually until it reached the zenith at about 11 p. m., being much fainter in illumination but still retaining the greater brilliancy around the outer edge. The rays or shoots were of uniform brightness over their whole length. At about 9 p. m. there appeared an aurora cloud extending in a southeasterly direction. The optical phenomenon was the most vivid observed in this locality for years. The delicacy of its beauty was more appreciable in the suburbs, as the city lights obscured the display from the observational tower.

Reading, Pa. (75th meridian time), *March 7.*—From 7:30 p. m. to 11:45 p. m. an aurora was observed. The sky was nearly covered with low clouds during the early evening until 9:30 p. m., but a faint red tinge could be plainly seen. After the sky cleared at 9:30 p. m. a red and at times yellowish tinges were observed, and were pronounced at several portions of the sky. Vibrating here and there in the northern portion of the sky a few quivering white streamers were seen which extended from the arch to close to the zenith.

* *Lafayette, Ind.*—On the evening of Thursday, March 7, a remarkable auroral display was visible here. Some observers report a faint red glow in the eastern sky as early as 7 o'clock, and it would appear from the testimony of several observers that the phenomena increased in brilliancy until about 9:45, at which time it was particularly striking. From the extreme northwest a broad band of deep red, like a cloud reflection of a conflagration, spread upward just south of the zenith, where it terminated within a horseshoe-shaped mass of white having the convex side toward the north. A similar but less brilliant red cloud extended from this point toward the east. Culminating at the same point within the horseshoe were greenish-white streamers extending in all directions to the horizon. At this time also there was another red patch covering somewhat more than the area of the Great Bear in the northeast. Athwart this ran the zenith streamers from the northern horizon.

At 10:45 p. m. the overhead display was fading and a broad red patch in the northwest covered Cassiopeia. This rapidly divided into two parts, drifting west and south.

By 10:30 the effect had practically disappeared except for a greenish glow toward the north.

Although the deep red color was massed in the streamers and patches mentioned, the entire sky was tinged with red, shading gradually outward from these dense masses.—*C. M. Smith, Purdue University.*

Notre Dame, Ind., March 7.—An exceptionally brilliant aurora occurred on the evening of March 7. It possessed features that had not been observed in auroras seen here in the past. It began about 7:30 p. m. At first shafts of white light were seen in the north. These extended upward over 90°. Later they were seen in the east and west and some in the south. Many of these met at a point a degree or two south and west of the zenith, forming a distinct focal point. The glow in the sky was brilliant and was of different colors—white, greenish-white, and red. This glow covered the sky with the exception of a portion of the south extending from the horizon upward about 45°. Two points were observed where the glow persisted, one in the middle of the eastern sky and the other about the middle of the southern. The aurora had about completely disappeared at 11 p. m.—*T. P. Irving.*

Valparaiso, Ind.—On March 7 there occurred a remarkable display of the aurora. Beginning about 7 p. m. as a pink-yellow glow and rising toward the zenith, by 7:30 it had developed the arch and was about 60° above the horizon. At 7:30 three areas of white light had formed, one in the southwest, one just east of south, and one in the southeast. The middle one was very vivid. At about 7:20 to 7:35 p. m. rather faint streamers of light resembling searchlight beams formed in the west between these areas and the main arch, and passed across to the east, occupying about 5 to 7 minutes in the passage. The main arch rose steadily, reaching the maximum at about 9 p. m., when it was about 20° south of the zenith. At 9:30 the arch had begun to recede and the three white areas began to fade. About 10 p. m. the color of the arch began to change to white, appearing first in the west. Numerous white streamers appeared from time to time radiating from the center of the arch. When last observed at 11:10 p. m. the arch had receded to about 25° above the northern horizon and was very faint.—*J. F. Bradley.*

Peoria, Ill. (90th meridian time), *March 7.*—The auroral display on the night of the 7th was probably the most brilliant seen in this section in many years. It began shortly after 7 p. m. and continued with varying but pronounced brightness till after 10 p. m., and with diminishing or faint illumination until after midnight. A considerable variety of forms appeared at different times, including a diffuse ill-defined glow, the arch, streamers, and irregular "clouds" of light. The colors seen were white, pink, a tinge of green, and orange; the effect was the most beautiful in the memory of many. All forms of display had a westward drift, but this was slower than the average observed here by the writer. The southward progression extended farther than usual. The colors apparently had a southward shift, from a point near azimuth 190° toward the zenith. The pink at times deepened to a pronounced orange. The uncolored "clouds" of whitish light were, at times, fully as distinct and prominent as are small patches of dense Ci. St. on a clear day; though at the same time stars shone through them with scarcely dimmed light.

The arch formation had its lower edge about 20° above the horizon, with the usual dark band below, and extended to about altitude 50° at the crown, and from about azimuth 130° to 230°. Later the arch was succeeded by somewhat irregular clouds of light. The southward advance of these carried their front fully 30° south of the zenith about 9:30 p. m. By that time the formation had dwindled to detached masses. The most notable display seen by the writer was at 9:35, when streamers or pillars of light on all sides were focused at the zenith, with a broad area of pink glow to northwestward which deepened to orange at about altitude 40°, azimuth 130°; the entire north at the same time being covered with irregular glow or patches of whitish light, with a flickering or dancing movement through it all.

* Reprinted from Popular Astronomy, No. 254, April, 1918, pp. 278-279.

* Reprinted from Science, Mar. 22, 1918, p. 291.

**Urbana, Ill.* (University of Illinois).—The most extensive and brilliant aurora witnessed in central Illinois within the memory of living men attracted unusual attention on the evening of March 7, 1918, at Urbana, Ill., in latitude 40° 6′ north, longitude 88° 13′ west. Although the aurora is only rarely visible here at all, this one reached beyond the zenith.

The aurora first attracted my attention at 9:25 p. m., central time, in the form of a band of white light about 2° wide, extending in an arc from a point on the horizon at about north 45° west across the north sky, reaching a maximum altitude of about 20°, approximately due north, and descending at about north 45° east. Through and beyond this, radiating white bands extending upward, and two rosy areas of about the color of the strontium flame appeared, one about north 45° east and 20° above the horizon, the other about north 10° west and 25° or 30° above the horizon.

The illuminated area extended rapidly, reaching a maximum at about 9:45 p. m., when it included the entire north half of the sky and overlapped into the south half from horizon to zenith. The main framework consisted of streamers of white light converging toward a point 30° or more south of and below the zenith. These streamers rose vertically from the north point of the horizon and its vicinity, but those rising from the east and west points of the horizon were inclined about 20° from the vertical (toward the south).

The streamers were fairly steady, in large part, extending, multiplying, and fading gradually; but in many parts of the sky there was a nearly continual play of light, in pulsations proceeding swiftly upward along the rays. Occasionally a streamer or a group of streamers brightened suddenly, giving an effect like that of the throwing on of a great searchlight.

Against the background of white streamers the red color expanded in glowing patches, increasing in brilliance as in area. During the maximum brilliance and extent of the aurora, the red was bright from the due east to the due west vertical circles and beyond them, and especially near the zenith (just below it to the north). It was never a continuous sheet of uniform brightness, but appeared brightest in roundish patches, locally streaking out parallel to the white streamers. The red lights pulsated and played up and down over the sky like the white.

About 9:50 p. m., after the aurora had faded slowly for a few minutes, the white streamers shortening to an altitude of 45° or less, the red light concentrated again in two patches, one about north 45° east and 20° above the horizon, the other north 5°–10° west and 25°–30° high. They varied from 3° to 10° or more in diameter. About 9:55 a third bright red area appeared, about north 40° west and 20°–25° above the horizon. It was less perfectly circular than the other two, having a tendency to show brightest and to expand along lines parallel to the white streamers.

About 10:05 p. m. the north 40° west and north 45° east red areas faded out, leaving a single glowing patch north-northwest 10° west and 20°–25° above the horizon, which continued to pulsate faintly and grow weaker. The white light had now subsided to a rather uniform sector of the north sky reaching from about north 50° west to about north 50° east and from the horizon to an arc whose maximum altitude lay in the site of the red patch in the north. At 10:45 p. m. there was still a glow in the north sky, apparent to an altitude of over 5°.

The angles here given were estimated, as I unfortunately had no instruments available at the time.—*C. W. Tomlinson.*

†*Urbana, Ill.* (University of Illinois Observatory).—Those who saw the aurora of August 26, 1916, did not expect to see such a display repeated within a lifetime, but on March 7, 1918, there was a similar spectacle which from reports must have been visible over practically all of the northern hemisphere of the earth. I first noticed the aurora low down in the north, about 7 p. m., but in half an hour clouds had come, which continued for an hour or so. At 9:30 I happened to be out of doors and saw that something startling was in prospect, as the sky was clear and the aurora was growing rapidly. The general effect and appearance of the display were accurately described by Dr. Tomlinson of our geology department [see above], and I shall limit my account to the determination of the position of the radiant or apparent focus of the auroral streamers. It was very striking that just when the display was at its maximum the streamers seemed to come from Saturn.

In the following notes central standard time, 6 hours slow of Greenwich is used, the position being latitude 40° 6′ north, longitude 88° 13′ west.

9h. 31m. Streamers rising. Cloud-like form in southeast.

9h. 36m. Radiant exactly at Saturn. Half of sky or more covered. To west and over Jupiter a broad band of red, 10° or 15° wide. This is southern edge of the aurora in that direction.

9h. 41m. Radiant 2° north of Saturn.

9h. 44m. Radiant 2° northeast of Saturn.

9h. 46m. Radiant fainter.

9h. 51m. Radiant has about disappeared.

9h. 51m. All of light is now below Polaris.

10h. 38m. Only faint glow low down.

No further display was noted by our observers at the telescope, who worked until several hours after midnight.

Averaging the three estimates, we have that at 9h. 40.3m. the radiant was 1.1° north and 0.5° east of Saturn. The magnetic elements for Urbana are: Declination 3° 13′ east, dip 71° 5′, determined by Mr. Merrymon in 1917, and kindly communicated by the superintendent of the United States Coast and Geodetic Survey. From the ephemeris position of Saturn, we readily find then for comparison:

	Declination.	Hour angle.
Magnetic zenith	+ 21.2°	+ 1.1°
Radiant	+ 20.1°	+ 0.2°
Difference	1.1°	0.9°

The result shows that within the error of estimate the apparent radiant or focus of the auroral streamers was at the magnetic zenith, which agrees with what was observed in 1916.—*Joel Stebbins.*

Davenport, Iowa.—The aurora was first observed at 6:50 p. m. low down on the northern horizon. At 7 p. m. its form was that of an arch crossing the northern horizon from east to west, with a maximum altitude of about 35° above the horizon. The color of the arch was greenish gray. Rose colored streamers crossed the arch radially at frequent intervals and faded quickly away.

The greenish arch rose higher in the sky shortly after it was first observed, and at 8 p. m. the highest point of the arc was about 70° above the horizon. By this time a second arc or band had also developed and extended as far south as the star Sirius. A dark space separated the two bands and the arches became broader and indistinct toward the east.

The maximum brilliancy of the aurora seems to have been reached at about 9:45 p. m. White streamers having the appearance of the most delicate cirrus clouds then extended from about 15° above the horizon, and from about 10° north of west to about 10° south of east, to a point about 5° south of the zenith, the general effect suggesting a gigantic canopy of some filmy material that had been drawn up and knotted loosely. This suggestion was heightened by a small, relatively dense area near the zenith, resembling a knot, beyond which the apparently loose end of the canopy extended a few degrees to the south. Beneath the base of the system of streamers the color of the sky varied from gray-blue to gray-green, the latter shade being almost identical with that frequently observed at the approach of dawn. Occasionally, two of the streamers, one about 20° west of north and the other about 30° east of north, became colored a rose shade, while the intervening space above the base of the streamers and to an altitude slightly above the Pole Star was suffused with a glow that suggested an enormous fire at a point some distance below the horizon. At such times the southern portion of the sky appeared intensely black to an elevation of more than 30°. Within a few minutes all traces of red or pink would fade out, leaving the streamers white, with the gray-green segment below and a peculiar misty effect close to the horizon similar to that produced early in the morning by a row of small trees set close together that are hardly discernible through a low fog. No trace of the usual dark segment could be observed at that time.

Shortly after 10 p. m. the streamers began to disappear and were wholly gone at 10:30 p. m. At 10:50 p. m. no trace of pink was any longer visible, although the faint green light could still be seen. The latter was last observed at 11 p. m.—*J. M. Sherier.*

Des Moines, Iowa (90th meridian time), *March 7.*—Beginning about 7:20 p. m., the aurora borealis became noticeable in the form of an arch of light in the northern sky at an altitude of about 25°. This rapidly enlarged, became brighter, and rose to an altitude of 60° by 8 p. m., the width of the arch being about 20° and extending from the eastern to the western horizon. About this time the flickering streamers of light known as "merry dancers" began to appear; also vivid colors, of which green predominated in the north and northeast and crimson in the northwest. About 9 p. m. broad bands of inky black, seemingly pivoted near the northern horizon, would appear in the east and rotate toward the west. A few minutes later large areas of light appeared in the south and gradually formed an arch of light at an altitude of about 30°. At 9:30 p. m. the entire heavens were ablaze with hues and shafts of light that rapidly changed into forms of endless variety, the predominating thing being shafts of whiter light that rose from the horizon at nearly all points, except a small arc in the south, and converged at a point a little—possibly 10°—southwest of the zenith. About 10:30 p. m. the display began to diminish, but some signs of it remained as late as 1:30 a. m. of the 8th. At times the light of the aurora was nearly equal to that of the full moon. This is probably the most brilliant display observed in this vicinity in many years. Telegraph service was much troubled by the magnetic effects of the aurora.

North Platte, Nebr. (90th meridian time), *March 7.*—An aurora borealis of unusual brilliance was observed from 8 p. m. of the 7th to after 12 midnight. The aurora consisted of a dark segment about 5° in width, above which was a whitish light, approaching at times a pale green, of

* From Science, Mar. 22, 1918, p. 291.
† Reprinted from Science, Mar. 29, 1918, p. 314.

about 19° or 20° in width. Above the white was a pink light, changing at intervals from a beautiful light pink to almost a red, this band being about 26° in altitude. At times narrow streamers of white light would shoot from the horizon to the zenith. The aurora was from 52° to 55° in altitude at its highest point; azimuth 120° to 250°.

Omaha, Nebr. (90th meridian time), *March 7–8.*—The most brilliant auroral display observed in years in this section began about 7:30 p. m. on the 7th and continued until about 2 a. m. on the 8th. When first observed the arch extended from about 100° to 265° azimuth and the center reached an altitude of about 42°, but constantly shifting streamers of light with well defined colors many times extended past the zenith. Reds, varying from dull copper to deep crimson tones, appeared at the extremities of the arch while blues, greens, purples and yellows predominated in the remainder. During the earlier part of the display parallel bands or rolls of light moved from the northwest across the sky to some distance beyond the zenith, and so bright were these that at times they blotted out the stars. By midnight the display had diminished to a pale green arch about 30° in height with considerable azimuth, but between 1:30 and 2 a. m. of the 8th brilliant streamers were again observed.

* *Peru, Nebr.*—We were favored here on the evening of March 7 by a magnificent display of aurora borealis. As soon as it was dark enough to see it, a great arch of pearly light appeared spanning the northern horizon, the center seeming to be a few degrees to the east of north. Here and there the arch would thicken and swell up like a great wave of light, from the crest of which streamers of greenish white, lavender, and red would shoot up, reaching and even passing the zenith at times. As a climax these streamers would fuse into another arch which would drift southward and dissolve, leaving usually a cloudy mass of greenish white or rose red light at the northeastern and northwestern ends of the new arch. This phenomenon was repeated many times, until finally the new arch passed the zenith and reached as far south as the belt of Orion, almost coinciding with the equator. The most wonderful displays came from 9:30 to 10 o'clock when the colors ranged from pearly white to greenish yellow, lavender, rose red, crimson, and cerise, until the whole northern half of the sky was lurid with variegated flames. The great constellations Leo, Orion, Taurus, Auriga, Cassiopeia and Ursa Major were swamped but not annihilated by the georgeous hues. Jupiter, Saturn, and Mars did not swerve a hair's breadth because of the threatening flames, though many people were frightened by the fiery glare of the latter through the crimson light, and were convinced that it had erratic movements. At the climax, two great streamers of pearly white light, much like gigantic comets, appeared in the northeast and northwest, reaching two-thirds the distance to the zenith. After 10 o'clock the exhibition gradually waned, until it was hidden by clouds about half past twelve.—*W. F. Hoyt.*

40° to 37½° N. lat.—Twenty-six reports were received from this belt. Where the aurora was most fully observed, it extended to 20° or more south of the zenith, even 45° and 60° S. being reported in Ohio. The display was brilliant, with shades of red, white, yellows and greens predominating, and with some purples. Tremulous, quivering, or pulsating streamers were reported generally, and one observer described the motion as "waving like electric fountains." The aurora began at dusk and lasted generally till about midnight, though some stations reported the aurora some time after midnight. Telegraph and telephone difficulties were reported: at Springfield, Ill., north-south lines were affected, while at Kansas City, Mo., only the east-west lines were influenced.

Springfield, Ill.—An auroral display, probably the most brilliant ever witnessed in this part of the country, was observed from 6:48 p. m. of March 7 to about 10:40 p. m. The phenomenon consisted, at first, of a perfectly formed arch of pale green light stretching across the northern sky from horizon to horizon. This band was about 15° wide. About 7:30 two spots appeared simultaneously at either end of the arch, extending upward in pulsating streamers of light until a secondary arch or semicircle was transcribed across the sky. This arch moved slowly southward, its crown eventually passing through and slightly beyond the zenith, where it rested for some time. The extremities of the upper arch remained at the east and west horizons long after the crown of the arch had disappeared, and these two sections became quite luminous at intervals during the continuance of the display. In the primary arch the altitude of the crown was 35° and the azimuth 195°; the azimuth of the western extremity was 130° and of the eastern 260°. The crown of the secondary arch passed through the zenith to a point 80° above the south horizon; the azimuth of the western extremity was 105° and of the eastern 285°.

At intervals streamers of soft vibrating radiance, the hues ranging from deep rose to purple, yellow, white, and green, extended upward from the main arch in sunburst effect, and were most pronounced a little to the west of north. Fields of dull crimson came into view intermittently, the brightest glows appearing in the west about 9:50, in the east about 9:55, and in the north about 10 p. m. All of these roseate illuminations, which would subside every few minutes to again appear in increased brilliance, were confined to the region lying between the two arches. There remained but slight traces of the luminosity at 10:30, and it had entirely disappeared at 10:42 p. m. Telegraph wires running north and south were noticeably affected during the display, but not those running east and west. The wires would alternately go out of commission and then return to normal.—*H. Merrill Wills.*

Hannibal, Mo. (90th meridian time). *March 7.*—A very brilliant aurora was observed at night. It was seen by some people soon after dark, but by the observer was first seen at 7:25 p. m., when it consisted of an arch of diffuse white light extending from about east to west and the upper edge at the elevation of and near the north star. The center seemed to be slightly east of the north star. This arch continued visible until after 11 p. m. At 7:40 p. m. beams of wavy columns of white light began to form near the east and west ends of the arch and move toward the zenith. At 7:55 p. m. a beam, a little south of the zenith extended at least 35° in length toward the eastern horizon. At 8:08 p. m. these beams extended from east to west and formed another arch about 10° south of the zenith. This second arch did not last long, but the wavy beams continued until about 9:10 p. m. About 9:10 p. m. a thin veil of wavy red light spread southerly from the northern arch to what seemed to be 10° to 15° south of the zenith and continued waving back and forth until about 9:40 p. m. At about 10:10 p. m. columns of bright and somewhat colored light emanated from the northern arch and reached nearly to the zenith. It is not known just how long these continued, but the northern arch was still visible at 11 p. m.

Kansas City, Mo.—The display was first observed at 7:30 p. m. as a faint, pale arch. By 7:55 p. m. a second arch appeared, extending from northwest to northeast, the altitude of the lower arch being about 8° or 10° and of the upper one between 15° and 20°. Both gradually extended upward until at 8:50 p. m. the upper one was at the altitude of Polaris and was becoming very dim, except at each end, which kept bright until nearly 10 p. m. The coloring at first was yellowish green, with faint bands or streams of light passing from one arch to the other and soon disappearing.

After 9 p. m. the northern sky became pink and a little later red in large patches, apparently having a drifting motion toward the southeast. The glow was not steady, but diminishing and increasing at short intervals and separating into patches perhaps 15° to 20° apart. Large patches of the sky were very red at 9:45 p. m. and a beam of gray light extended from the north horizon to the zenith. There was a slight tremulous motion for a short time at 9:45 p. m. of greenish streamers separating red areas. The last visible was a reddish glow in the northeast at an altitude of 20 to 25°, which disappeared at 10:10 p. m.

The sky was perfectly clear during the display and no clouds followed.

East-west telegraph lines were affected quite sensibly, while north-south lines did not seem to be influenced. This statement was made by an Associated Press attaché.—*P. Connor.*

St. Louis, Mo.—A brilliant aurora was observed at this station on the evening of March 7, 1918. The first streaks were noticed shortly after 7 o'clock, they had the appearance of thin, whitish cloud. Shortly after this, as was reported by a number of persons, greenish streamers made their appearance. The writer first saw the phenomenon at 9:25, when whitish streaks were observed rapidly lengthening and mounting toward the prime vertical. As they shot upward they changed rapidly to pink. Very soon the streamers coalesced, forming patches of color. Throughout its duration the aurora drifted at a perceptible rate from east-northeast to west-southwest. As the fields of pink passed the meridian and entered upon the western part of the heavens they changed first to bright red and farther on to deep red. A patch of sky in the northeast also was deeply colored. At the time of most striking display, about 9:40, there was a white band, 3° or 4° in width, extending from near the western horizon, through and past the zenith; a similar ribbon extended from the eastern horizon toward the above-mentioned band, but the two did not meet. Attending a temporary fading of the pink in the northeast, there developed a crescent-shaped field of white, approximately 30° above the horizon, azimuth about 225°. It was about 30° in length and resembled a portion of cirro-stratus cloud, highly illuminated. The points of the crescent pointed toward the east. Other bright areas were also observed at a few points. Clouds were not observed, unless some of these white patches were such, brightened by the auroral beams.

The stars were obscured in many places by the white and red patches. The principal illumination ended about 9:50, though for some time thereafter isolated streamers were to be seen. At its maximum development the radiance did not extend beyond the prime vertical except throughout a limited area near the western horizon.—*H. Tullsen.*

Concordia, Kans. (90th meridian time), *March 7.*—An unusually brilliant exhibition of the aurora borealis occurred in this vicinity

* Reprinted from Popular Astronomy, No 254, Apr., 1918, p. 279.

to-night. The display was first observed at 7:45 p. m. It then consisted of a luminous whitish-yellow bow, with a dark segment hanging below; presenting the appearance of a dark-wood alter covered with a white velvet cushion. The bow, or arch, extended from azimuth 140° to 225°, having an altitude of about 15° at each end, and about 20° at its center. A brilliant, diffused light filled the northern and eastern sky during the display, which lasted until 11:10 p. m.

From 8:15 to 10:35 p. m. a thin, red, cloud-like, ragged veil was noted in the northeastern sky, extending from azimuth 195° to 220°, its altitude being about 35–45°. This cloud-like formation was very thin, stars behind it shining with uniminished intensity.

Four bands, or streamers, of pale yellow light, tinged with green, flaring from the arch to an altitude of about 60°, were observed from 8:20 to 11 p. m. These bands were each about 3° wide, with their centers at 162°, 175°, 185°, and 202° azimuth, and were sufficiently dense to dim materially the light of stars behind them.

Topeka, Kans. (90th meridian time), *March 7.*—An unusually fine display of the aurora borealis was observed from 7:15 p. m. to 10:30 p. m. on the 7th. The auroral arch was well defined, rising about 20° above the horizon at its highest point, which was slightly east of north. The upper edges of dark segment, which formed a part of the auroral arch, were a silvery white like a dark cloud illuminated by a moonrise behind. The finest display of streamers occurred at 7:15 p. m. when as many as 25 were counted at one time, reaching an elevation of 60° at the highest point. By 7:50 p. m. these streamers had diminished somewhat in brightness, but were still in evidence, with velvety reddish glow covering a patch about 20° square in the northwest sky. At times a part of the dark segment would become detached and move slowly toward the zenith, having a shape somewhat like a rainbow and being illuminated on its upper edge with a silvery whiteness. At about 9 p. m. a mass of detached auroral clouds shown with an unusually white light in the northeast.

By 10:30 p. m. the display had greatly subsided and practically all that was left was the dark segment, with its silvery illuminated arch in the north.

No trouble with telegraph or telephone service was reported locally on account of the display.—*S. D. Flora.*

Wichita, Kans. (90th meridian time), *March 7.*—An aurora was observed during the evening of the 7th from 7:40 p. m. until shortly after 10 p. m. During the earlier portion of this time, it extended as a bright white band of light arched across the northern sky from about azimuth 135° to about azimuth 245°, the top of the arch at times extending upward from 30 to 45°. A rose-colored tint was observed for a time in the aurora in the northeast, and white streamers of light were pulsating upward from the arch at different points. Toward the end of the period mentioned the aurora became less distinct, except that from about 9:35 p. m. to about 9:45 p. m. a brilliant display of rose-colored streamers occurred above the auroral band in the northeast and north.

Baltimore, Md. (75th meridian time), *March 7.*—A brilliant aurora observed from 7:45 p. m. to 11:30 p. m.

Washington, D. C. (75th meridian time), *March 7–8.*—The aurora borealis of the night of March 7–8 was first observed about 7:30 p. m., and at times was of unusual brilliance. It took the form of an arch of light in the north. At one time, about 10 p. m., three arches were observed, showing at intervals brilliant colors of red, purple, and gold. It disappeared about 2:30 a. m. of the 8th.

Lexington, Ky. (90th meridian time), *March 7.*—At 7:45 p. m. attention was called to the aurora, consisting of a dark segment of a circle, the center resting below the pole star, with three greenish bands. Concentric with this, each about 6° wide and separated from each other about 10°, the lower being below the pole star, and the others beyond, the outer reaching an altitude of about 60°, and cutting the horizon at azimuths 110° and 250°. The outmost band was at times only fragmentary with conical termini. Mars and the Pliades were both at one time within the limits of the outer band. This gradually faded away till by 8:30 p. m. no colors were visible.

At 9:30 p. m. another observation was made and an amazing spectacle was in progress. The forms had greatly changed. A dark band was barely visible in the north. At northwest and northeast points rosy streamers 20° to 25° in breadth with a darker intervening space centered at north, occupied the sky. The darker space was streaked with brilliant greenish flashes, all colors momentarily varying in height from 50° to 60° to bursts like electric fountains, almost meeting from all sides in the zenith. By 9:45 p. m. the brilliancy considerably diminished, yet visible from the immediate proximity of street arc lights. The northwestern and northeastern glows faded by 10 p. m., while in place of the greenish streaks in the north appeared a broad rosy glow, gradually diminishing and finally disappearing by 10:05 p. m.

No telegraph disturbances were noted, but clicking sounds were heard in telephones, and one party was unable to use a phone at 9:50 p. m.

Cincinnati, Ohio (90th meridian time), *March 7.*—On the evening of the 7th at 6:45 p. m. a dim glow of light was observed in the north and northwest, but did not show any form. By 7:05 p. m. a fairly well-defined aurora borealis extended along the northern horizon above a band of smoke and haze. At 7:08 p. m. a pale red glow appeared in the northeast, above the east end of the arch, which gradually increased in size and spread into the north, where faint streamers extended rapidly to 45° above the horizon. A second arch of pale gray light formed above the first with about 3° of dark sky between. After a few minutes the two merged together and by 7:20 p. m. the red glow had disappeared, but the arch continued in the north. At 7:55 a bright patch of light appeared in the northwest and rapidly extended eastward, resembling somewhat the broad beam of a powerful searchlight, and forming a complete arch, which disappeared in five minutes, first in the west and last in the east. The main arch in the north gradually increased in altitude until 8:15 p. m. the center was probably 30° or 35° above the horizon, at the whole northern half of the sky was irregularly illuminated with white or gray light. During the following hour several arches or fragmentary portions of arches formed across the sky. They were continually changing in form and distinctness and extended mostly from north of west to south of east. Some were nearly through the zenith and others were south of the zenith. At 8:20 p. m. portions of three arches were visible at altitudes of about 45°, 70°, and 90°, respectively, above the southern horizon. The middle one of these arches was remarkably bright and complete. A glow of pale pink light appeared in the northeast at 9:30 p. m. and increased rapidly in size, becoming a deep red. Streamers shot rapidly up and formed one after the other farther to the west, finally extending into the northwest. The streamers extending up from the horizon directly in the north, were visible 15° beyond the zenith. From 9:37 to 9:50 p. m. the whole northern half of the sky was covered with a brilliant mass of bright red streamers, interspersed at numerous places with patches of gray or white light and forming a gorgeous auroral display. After this time the light began to fade in all parts of the sky and by 10:15 p. m. the aurora had disappeared.

Dayton, Ohio (90th meridian time), *March 7.*—An unusual auroral display was observed on the 7th, beginning about 7 p. m. and continuing till near midnight. Early in the evening a band or arch of white light extended across the sky from east to west about 30° above the south horizon. At about 7:30 p. m. a second arch appeared at about 45° nearly parallel with the first, and the latter became greatly intensified and very bright. The 45°-arch disappeared after about 15 minutes and bright spots appeared in the eastern sky, with streamers reached to about 90°. At 8:45 there were streamers running across the sky from northwest to southeast and at 9:30 p. m. the display was o' marked brilliancy with streamers from the north' and the sky became rose red. The entire display began at azimuth 105° and ended about azimuth 290.°

Indianapolis, Ind. (90th meridian time), *March 7.*—Aurora first observed 7:40 p. m Appeared as a hazy band of light 10° to 15° wide, in the form of a flattened rainbow. The maximum point was 45° above the horizon in the north, and the two ends faded away in the northeast and northwest. At 8:15 the streamers extended from two points near the horizon, west of northwest, and east of northeast, respectively, upward and diverging. The condition was most distinct at 9:30 p. m. No trace of the aurora could be detected after 10:15 p. m. The telegraphic service was very poor during the period in which the aurora was visible. Variable earth currents were reported by the local operator. The currents were most noticeable west of Chicago and east of Pittsburgh.

37½° to 35° N. lat.—The 16 reports from this belt indicate that the aurora was confined to the northern sky, reaching, however, almost, if not quite, to the zenith. Even here, the aurora was very brilliant, and streamers were observed everywhere, although no quivering of the lights is mentioned. Reds predominated; yellows, greens, and white were reported generally, and at one place blue also. The aurora was first seen at dusk and lasted generally till 10 or 10:30 p. m. (90th meridian time). At Bentonville, Ark., however, the aurora was visible till about 2 a. m. the 8th. Telegraphic disturbances were reported at two places.

Lynchburg, Va. (75th meridian time), *March 7.*—An auroral display of unusual brilliancy occurred on the night of the 7th. At 8:15 p. m. when first observed it was of the arc form, extending east and west through about 50° and to an altitude of about 18°. The arc separated a bright silvery glow from the dark sky above it. Along the arc was a red fringe with patches of deep red. No streamers were then present. The intensity of illumination increased to its maximum at 10 p. m. and afterwards decreased until 11 p. m., when it had almost entirely disappeared.

Soon after 9 p. m. the rays gradually appeared, the arc became fainter, and finally the northern skies were filled with diffused light, chiefly red and yellow, and many rays some of which converged. One of the most striking features observed was a ray about 3° wide that came from a point due north and gradually rose to the zenith.

While the display was at its best the diffused light reached an azimuth east and west of 45° and altitude of 80° and at times 90°.

Raleigh, N. C. (75th meridian time), *March 7.*—An aurora was observed from 8:15 p. m. to 11:15 p. m. The only distinctive feature was the illumination of the northern sky line to a height of about 30°. The predominating colors were red with a slight tinge of green until about 9:45 p. m., after which green replaced the red, gradually becoming faint and disappearing.

Chattanooga, Tenn. (90th meridian time), *March 7.*—An aurora borealis was observed by a large number of citizens, from about 8:30 p. m. to 10 p. m. in the north, extending from about 20° west of north to 20° east of north, and the crest of the arc was about 25° above the horizon. The arc was of a pale yellowish red, tinged with green, resembling the reflection of a large fire. No streamers were noted. The telegraph wires were affected.

Nashville, Tenn. (90th meridian time), *March 7.*—On the 7th a pronounced display of the aurora borealis was observed from about 8 p. m. to about 10:30 p. m. In the early part of the display there were three distinct arcs or arches of yellowish green light (some described it as whitish) extending across the northern sky. The two lower arcs were almost continuous from east to west extremities, and at the center, or crown, reached a height of probably 30° above the horizon. The third or highest arc was visible only as two or more patches of bright glow to the right and left of the center, and if it had extended across the north the crown would probably have reached 40° above the horizon. The azimuth of the western extremity was about 110° and of the eastern about 280°. The center of the arches was from 5° to 10° east of Polaris. The bands extended almost as far east and west of Ursa Major and Cassiopeia, respectively, as these castellations are distant from Polaris. The display was continually undergoing changes in appearance. The yellowish or whitish arcs, which at first were more or less continuous, were later broken up by dark areas and appeared as patches of illumination, varying in size and intensity. Between 8:30 p. m. and 9 p. m. a very faint reddish glow appeared in the northwest, and by 9:45 p. m. this had assumed a brilliant hue enveloping practically the entire northern sky and extending easily to the zenith. This was spread out as an even sheet of red, although there appeared through it, especially in the northwest, shafts or streamers of red light brighter than the rest. Some persons reported streamers also of whitish light, but in the city the streamers did not appear strong or of much duration. For the first hour the appearance was somewhat of the eastern sky just before the break of day. At 10:10 p. m. no trace of the aurora was visible.

Springfield, Mo.—On the evening and night of March 7, 1918, the sky was clear at Springfield, Mo., and an aurora was distinctly visible from 6:40 p. m. to about 10:15 p. m.

At 6:40 p. m. it consisted of bars of light in the northern sky of varying degrees of luminosity, extending upward about 20° and showing distinct coloring, dull red in the northwest and a bluish tinge in the northeast. By 7:45 p. m. it was brighter and extended upward about 35° and seemed to consist of a primary bow rising almost due east and setting in the northwest.

At 9:25 p. m. there was a whitish arc about ½ a degree in width extending from the eastern horizon to the northwestern horizon, its altitude being about 15° at the highest point. Beginning at the east, white and rose-colored streamers or shafts extended upward from the arc and the same phenomena were forming toward the northwest. These streamers spread rapidly upward and outward within a few minutes time, reaching almost to the zenith, and coloring the northern sky above the arc a rosy red. At a point in the northeast (azimuth about 235°) and in the north (azimuth about 190°) the streamers grew longer and brighter than at the other points of the arc. A faint greenish-white light appeared beneath the arc extending downward almost to the horizon. The streamers were at their maximum height and luminosity at 9:30 p. m., but soon receded and at 9:45 p. m. appeared as a luminous cloud that gradually deepened into night at about 10:15 p. m.—*W. B. Hare, and W. W. Talbott.*

Oklahoma, Okla. (90th meridian time), *March 7.*—A brilliant aurora was observed on the night of the 7th from 9:40 p. m. to 10:20 p. m. When first noted it was merely a glow in the north, on what seemed to be a thin white cloud bank, running from north to northeast. The color, or light (a deep pink or rose) soon spread and covered a large strip of sky between the north and northeast and from 9:45 p. m. to 9:47 p. m. it seemed as though several powerful searchlights were trained upon the upper part of the cloud, or curtain of color. The beams, however, did not reach the zenith nor did the base of the "curtain" reach the horizon. The color, or light, drifted from the north to the northeast and disappeared at 10:20 p. m. Stars were plainly visible through the curtain. Many 'phone calls were received at this office regarding the display. Many were of the opinion the light was due to the reflection on the clouds of a large fire somewhere to the north of the station and the streamers due to a battery of searchlights playing upon it. The color during the greater portion of the display was vivid.

35° to 32½° N. lat.—The 5 reports from this belt indicate that the aurora extended only about half way to the zenith up from the northern horizon. Some streamers were seen, and at Fort Worth, Tex., "a pronounced vibrating motion was noticeable." Red was the only color reported. Except at Little Rock, Ark., where the aurora was seen as early as 7:30, the display was noticed only between 9 and 10 p. m. (90th meridian time), the time when it was most brilliant farther north.

Little Rock, Ark. (90th meridian time), *March 7.*—An auroral display was observed between 7:30 p. m. and 9:30 p. m. It had the appearance of a red tinted cloud in the heavens about 10° to 20° above the horizon. Streamers shot from the body of the display toward the zenith reaching an altitude of about 40° to 50°.

Dallas, Tex. (90th meridian time), *March 7.*—An aurora borealis, or northern light, was observed from 9:35 p. m. to about 10 p. m. The arch light was red and first observed to the north-northeast near the horizon and appeared to spread upward and westward until it extended from northwest to northeast and was visible over an area of altitude of about 10° to 45°. Band-like streamers were observed perpendicular to the arch.

Fort Worth, Tex., March 7.—"The aurora was noted between 9 and 10 p. m. local time. The color was generally deep red, and about halfway between horizon and zenith. The width subtended an angle about 8° to 10° and the length about 60°. A pronounced vibrating motion was noticeable. Domestic animals became frightened and showed uneasiness, dogs trying to get into the house and whining."

32½ to 30° N. lat.—The 6 reports from this belt show that the aurora was a rather bright red arch extending up to 30° above the northern horizon, seen from 9:15 to 10:30. At Taylor, Tex., however, the display was visible from about 7 p. m. to 1 a. m.

Vicksburg, Miss. (90th meridian time), *March 7.*—An aurora borealis was observed from 9:30 p. m. to 10:30 p. m. From the accounts of those who saw the phenomenon it appears that the aurora was visible in the north over an arc of about 60° to an altitude of about 30°, and it was of a reddish tint, at times rather bright.

Alpine, Tex. (Brewster County), *March 7.*—From about 9:30 p. m. to 10:30. Queer red reflection in northeast (resembling a large fire), flaring up for about 10 minutes near 10 o'clock; covered arc of 30°.

Taylor, Tex. (90th meridian time), *March 7.*—An aurora borealis was observed on the night of the 7th. It was seen in the north from about 7 p. m. to midnight. It had the appearance of a large and distant fire, having a yellowish hue. It extended about 22° above the horizon. Telephone reports from Austin and points in this vicinity gave information of the appearance of this phenomenon throughout this section.

30° to 27½° N. lat.—Five reports indicate that the character of the display was practically the same as in the next belt farther north. Even some streamers were seen at Winter Park, Fla. The display was observed generally from 9:15 to 10, although at Bartow, Fla., it lasted till 11 p. m. (90th meridian time). Long-distance telephone communications were difficult from Tampa, Fla.

Winter Park, Fla., March 7.—The aurora of March 7 was seen at Winter Park, Fla. (latitude about 28° 37′ N.). It was visible for a short time only between 9:30 and 10 p. m., Central Standard Time. Those who saw it described the sky as brilliantly red for perhaps 40° along the northern horizon, with streamers extending halfway to the zenith.—*Frank P. Whitman, in Science, April 19, 1918, page 393.*

27½° to 25° N. lat.—The 1 report from Miami, Fla., is self-descriptive.

Miami, Fla. (90th meridian time), *March 7.*—An aurora, the first of record at this station, occurred during the early part of the night of the 7th–8th, being observed by many persons between the hours of 9:15 p. m. and 10 p. m. Descriptions by several observers indicate that the phenomenon appeared as a brilliant illumination of the northern sky, the color being a dull red. The altitude of the crown above the north point of the horizon apparently was between 15° and 20°. The azimuth of the extremities is not known. No streamers or bands were observed.

WOLFER PROVISIONAL SUN-SPOT RELATIVE NUMBERS.*

The provisional relative sun-spot numbers given in Table 1 herewith are in continuation of the observed relative and the smoothed relative sun-spot numbers published in the REVIEW for July, 1915, **43**: 314.

While these provisional numbers are subject to slight revision, and later will be smoothed by the method described in the REVIEW for April, 1902, **30**: 171, they are sufficiently accurate to show that at the crest of the maximum of 1917 the relative sun-spot number was in excess of 100, which is unusually high.—*H. H. K.*

TABLE 1.—*Wolfer provisional sun-spot relative numbers, January 1915–December, 1918.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Mean.
1915 [1]	25.7	35.6	34.9	42.2	35.0	69.9	71.0	68.6	44.7	53.5	38.2	32.7	46.0
1916 [2]	44.3	55.4	66.5	73.3	71.4	67.7	53.0	34.1	41.4	56.0	60.7	41.0	55.4
1917 [2]	76.2	71.8	86.6	63.7	112.7	113.8	117.0	143.2	121.9	71.4	90.1	116.8	98.8
1918 [3]	96.3	63.4	72.2	76.5	76.5	64.8	104.6	94.1	73.5	86.1	68.0	54.8	77.6

[1] Met. Zeit, 1915, **32**: 188, 364, 508, and 1916, **33**: 42.
[2] Terr. Mag. Sept., 1918, **23**: 136, **24**: 43, and others.
[3] Replacing data in this REVIEW, September and December, 1918, **46**: pp. 403 and 574.

Sun-spot numbers are determined by a somewhat arbitrary rule, but they are approximately proportioned to the spotted area of the sun. One hundred as a sun-spot number corresponds to about one five-hundredth of the sun's visible disk covered by spots.—*Met. Off. Circ., 23, Apr. 25, 1918.*

In reporting on the sun spots observed in the year 1918 Mr. Evershed, director of the Solar Physics Observatory, Kodaikanal, remarks that the maximum spot activity of the present cycle took place during the second half of 1917 for both hemispheres. This judgment may be accepted as correct, for though some hesitation has been felt in accepting this early date lest a secondary maximum should occur after a temporary decline, as has happened in previous cycles, these circumstances do not seem likely to occur. The date of the previous maximum has been placed in the early part of the year 1906, though the sun-spot activity of that year was inferior to that of 1905 and of 1907. Adopting these estimates as correct, the length of the period just ended is slightly above the average.—*Nature (London), June 12, 1919, p. 291.*

THE WEATHER DATA NEEDED BY ECLIPSE EXPEDITIONS.

In spite of the fact that some of the observing stations for the total eclipse of May 29, 1919, were in the equatorial rain belt, satisfactory results have been obtained.

"In connection with the coming solar eclipse of September 10, 1925, the path of totality of which crosses Mexico, Prof. W. W. Campbell renews a suggestion which has been made by Prof. Todd and other astronomers, viz, that weather observations should be made along the prospective shadow path for a few years before a total eclipse, not only at the season of the year in which the eclipse is to occur, but also at the hour of the eclipse. The observations made at the regular term-hours at meteorological stations often give an entirely erroneous idea of the kind of weather likely to be encountered at the time of an eclipse. Prof. Campbell says that the data supplied to prospective observers of the Russian eclipse of August 21, 1914, were based on observations made in the morning and evening, and gave fair promise of clear skies for the event. After the eclipse parties reached Russia they were surprised to discover that while clear weather was the rule in the evenings and mornings and at night, cloudiness generally prevailed in the middle of the day, reaching its maximum at about the eclipse hour. The Lick Observatory would not have sent an eclipse expedition to Russia if this condition had been known. * * *—*Sci. Amer., New York, June 21, 1919, vol. cxx*, p. 649.

LAND AND SEA BREEZES IN THE VICINITY OF CORPUS CHRISTI BAY, TEX.*

By C. E. HECKATHORN, Observer.

[Dated: Weather Bureau, Corpus Christi, Tex., May 17, 1919.]

SYNOPSIS.

Corpus Christi Bay is almost a land-locked body of water, 20 miles wide from east to west and 16 miles from north to south and 14 feet deep. The result of these physical factors is that Corpus Christi Bay is considerably warmer than the Gulf of Mexico, and, at night, very much warmer than the adjacent land areas. It is situated south of the paths of HIGHS and LOWS so that its temperature and winds are little affected thereby. With such striking differences in land, bay, and sea temperatures it follows that the land and sea breezes present an interesting study.—H. L.

Corpus Christi Bay is an almost land-locked body of water about 20 miles in length east and west by about 16 miles in width north and south and is far enough south (north latitude 27° 40′ to 27° 56′) so that the winds and temperatures of the vicinity are not dominated by areas of high and low pressure that cross the United States during the summer season (see fig. 1). It is separated from the Gulf of Mexico by Mustang Island, which is quite narrow and is one of the chain of narrow islands paralleling the Texas Coast. The bay has only two connections with the Gulf of Mexico, Corpus Christi Pass at the south and Aransas Pass at the north end of Mustang Island. Both passes are quite narrow and Corpus Christi Pass is shallow, having a depth of less than 3 feet; allowing only a very limited mixing of the water n the bay with the water in the gulf. Extending southward from the east end of the bay is a long narrow body of water, Laguna Madre, which has no other connection with the Gulf of Mexico except at its southern extremity, over one hundred miles south of Corpus Christi Bay. Laguna Madre is shallow, being less than 1 foot in depth in most places and only a few feet in depth in the deepest places. Extending northeastward from the northeastern extremity of Corpus Christi Bay is Shoal Bay; a body of water similar to Laguna Madre. The Nueces River enters the western extremity of Corpus Christi Bay through Nueces Bay, which is also shallow; permitting the water of the river to be affected by radiation so much before entering Corpus Christi Bay that it is near the temperature of the surrounding land when it enters Corpus Christi Bay. Corpus Christi Bay has an average depth of about 14 feet and is quite uniform in depth except near the shores.

In the summer season, owing to almost uninterrupted insolation, almost complete separation from the Gulf of Mexico, and the relatively high temperature of most of the water entering it, the water of Corpus Christi Bay becomes much warmer than the water in the Gulf of

* For other recent discussions of sea breezes locally on the coast of the United States see "Sea breeze on eastern Long Island," by E. S. Clowes, Monthly Weather Review, 1917, **45**: 345-346; and in "Certain characteristics of the winds at Mount Tamalpais, Calif," by H. H. Wright, ibid., 1916, **44**: 514.—EDITOR.

Mexico. During the daytime in the summer, the water of the bay is much warmer than the water of the Gulf, and at night the water of the bay is considerably warmer than the water of the Gulf and very much warmer than the surrounding land surface.

It is evident that these differences of temperature must have considerable influence on the winds of the vicinity, and it is greatly to be regretted that it has not been possible to take sufficient temperature readings to be able to show the extent of these differences.

The winds of the west Texas coast region, except where influenced by local causes, are from the southeast almost continuously all summer. The land and sea breezes are the principal cause of variations in wind direction and velocity and the winds along the coast are a combination of the prevailing southeast winds and the land and sea breezes, except for the irregular changes caused by the passing of high and low pressure areas and the variation in the intensity of heat over the interior of the continent. As the land and sea breezes never have an opportunity to develop independent of the prevailing southeast winds, their force can be determined only by their modifying influence on the prevailing winds. In clear weather,

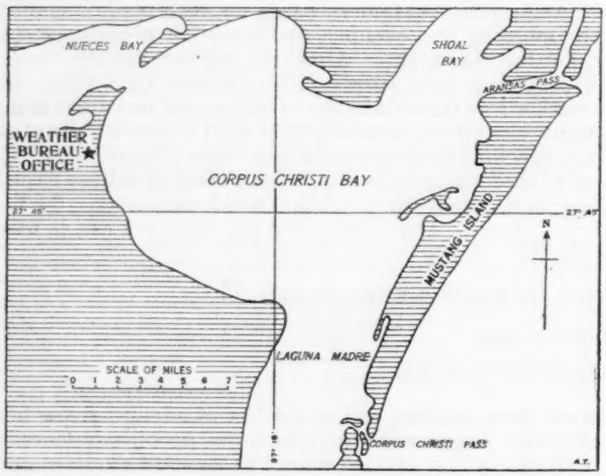


FIG. 1.—Corpus Christi Bay, Tex.

this modification of the winds is sufficiently great to permit of a fairly accurate estimate of the force and duration of these winds. As the general outline of the coast is nearly due north and south, the land breeze acts from nearly due west and the sea breeze from nearly due east except where influenced by the local heating of the water in Corpus Christi Bay. Since the sea breeze and the prevailing wind blow from so nearly the same direction, it is by means of the differences in the velocities at different hours of the day that the force of the sea breeze can best be judged and by this means of judging, it would appear, that under the best conditions of the atmosphere for insolation in midsummer, the sea breeze on the open coast has nearly as great force as the prevailing wind, which averages about 14 to 16 miles per hour. During the early summer, the prevailing winds are stronger and the sea breezes weaker, and during the late summer both are weaker than in midsummer. The sea breezes diminish very rapidly in force with conditions that are not favorable for strong insolation.

The force of the land breeze can best be judged by the modification of wind direction caused by the land breeze. The land breeze is much weaker than the sea breeze, as is shown by the fact that under the best conditions for radiation the wind in the early morning is a gentle breeze from south-southwest on the immediate coast and nearly due south only a short distance to sea, indicating a force somewhat more than half the force of the prevailing winds.

Corpus Christi, being near the middle of the western end of Corpus Christi Bay, has nearly the same directions for land and sea breezes as have places on the coast north and south of the bay; that is, nearly due east for sea breezes and nearly due west for land breezes, so that whatever influence the bay has on land and sea breezes must be noticeable in changes in velocities rather than in modifications of the directions.

On the coast north and south of Corpus Christi Bay the sea breeze becomes noticeable between 9 and 10 a. m. and is indicated by a rapid rise in velocity and a shifting of the wind toward the east. At Corpus Christi the sea breeze does not become noticeable until between 10 and 11 a. m. and is indicated by a gradual rise in velocity and nearly the same shift in direction as is noticed on other parts of the coast. Along the southern shore of the bay the shift of the wind to the east is somewhat more marked than at Corpus Christi and on the north shore of the bay little if any shift in direction is noticeable, although the gradual rise in velocity is experienced. The later appearance of the sea breeze on the shore of the bay is evidently due to the fact that the bay is so warm that it takes from one to two hours longer in the morning for the land to reach a temperature sufficiently high to develop a sea breeze on the bay shore than on the Gulf shore. It is also noticeable that the wind during the middle of the day is considerably stronger along the Gulf shore than along the shores of the bay. At Corpus Christi on days in which insolation is strong the maximum wind velocity is reached usually about 5 p. m., which is probably somewhat earlier than the time of maximum wind occurrence at points along the Gulf coast.

When the sea breeze becomes well established there is a veering of the wind to nearly the same direction as the prevailing wind, due in part to the greater deflective effect of the earth's rotation on the stronger breeze and in part to the increased speed of the general wind during the hours of considerable convectional activity. Thus, there is no shift of the wind at the time of the dying out of the sea breeze, and the only way of determining the time of the ending of the sea breeze is by noting the time when the velocities decrease. The decrease in velocity begins about 5 p. m. at Corpus Christi, but the decrease, like the morning increase in velocity, is gradual.

The first sign of the appearance of the land breeze at all points along the coast, is a slow shifting of the wind toward the south. The next indication is the forming of small cumulus clouds over the Gulf a few miles outside of the chain of bordering islands. These clouds appear first opposite Corpus Christi Bay and an hour or so later along the rest of the Gulf coast, indicating that the land breeze begins over the bay some time before it begins over the Gulf. These clouds mark the place where the prevailing winds are checked by the land breeze and the surface air of the prevailing wind forced to rise and pass over the land breeze, or, in other words, mark the farthest seaward limit of the land breeze. It is noticeable that these clouds are at about the same distance outside of the bordering islands on the whole coast line and that they are farther out to sea in the morning than they are in the evening. These clouds soon become flattened on their tops, thus showing the well-known shallow depth

of the sea breeze and the elevation at which the upper portions of the clouds are carried forward toward the land and dissipated by mixing of the cloudy air with the drier air at that elevation and the drier air rising from the bay. These clouds move slowly toward the north all night. The off-shore clouds are always quite low, although they vary considerably in the elevation of both base and top on different nights. The base of the clouds average in the neighborhood of 800 feet in elevation, which is somewhat higher than the theoretical elevation at which the moisture in the surface air should become sufficiently cooled to condense and form clouds. On clear bright nights, when radiation is most effective, the tops of the offshore clouds are much higher than when radiation is not so effective, which, as would be expected, indicates that the land breezes are much deeper on such nights than on nights when radiation is not so effective. The tops of these clouds are, on an average, about 1,500 feet during July and August and somewhat lower earlier and later in the season. In the morning, soon after the sun begins to warm up the land surface, the offshore clouds begin to move toward the land all along the coast, except opposite Corpus Christi Bay. The offshore clouds opposite the bay move somewhat more rapidly toward the north for more than an hour after the clouds farther north and south have passed inland. When the clouds opposite the bay reach a point nearly opposite the northern extremity of the bay, they turn sharply toward the northwest and move rapidly inland. The wind at Corpus Christi continues to blow from the south-southwest for more than an hour after the clouds north and south of the bay have passed inland.

About an hour and a half after sunrise the wind at Corpus Christi reaches its minimum velocity, which is usually a gentle breeze from the south-southwest, but occasionally from the southwest or west-southwest. After the minimum velocity is reached the wind gradually increases in velocity and shifts toward the southeast. An hour after the minimum velocity has occurred the wind is in the southeast and is increasing rapidly in velocity.

On the whole, it appears that this shallow superheated bay has the effect of delaying the appearance of the sea breeze in the morning and of hastening its end in the evening, as well as of weakening its force while it is blowing, but it would also appear that the course traveled by the sea breeze is somewhat longer than it would be if there were no such body of water to affect it. The land breezes are no doubt lengthened in duration, both in the morning and in the evening, and their force is considerably greater than would be the case if there were no bay

LAND AND SEA BREEZES AT BAYONNE, FRANCE.

By M. ROUCH.

[Comptes Rendus, Feb. 10, 1919, vol. 168, pp. 313-315.]

(Translation and abstract.)

From hourly observations of wind velocity and direction made at the aviation center at Bayonne at the southern end of the Bay of Biscay on clear days or days on which the cloudiness did not exceed 4/10, the author brings out the following facts:

1. Table 1, giving hourly components of the wind, was obtained by considering the observed wind at any hour to be made up of two components—i. e., the mean wind for the season and the hourly wind. By taking one side of a parallelogram proportional to the mean wind and the other side proportional to the observed wind, the diagonal gives the hourly wind.

TABLE 1.—*Hourly components of the wind at Bayonne, France.*

Hours	1 h.	2 h.	3 h.	4 h.	5 h.	6 h.	7 h.	8 h.
Direction	S. 13° E.	S. 22° E.	S. 25° E.	S. 26° E.	S. 27° E.	S. 29° E.	S. 27° E.	S. 24° E.
Speed (m. p. s.)	1.2	1.7	1.8	1.7	1.7	1.9	1.8	1.5
Hours	**9 h.**	**10 h.**	**11 h.**	**12 h.**	**13 h.**	**14 h.**	**15 h.**	**16 h.**
Direction	S. 17° E.	S. 04° E.	N. 66° E.	N. 13° E.	N. 7° W.	N. 12° W	N. 8° W.	N. 11° W
Speed (m. p. s.)	1.2	0.7	0.2	0.5	1.4	2.3	2.9	3.0
Hours	**17 h.**	**18 h.**	**19 h.**	**20 h.**	**21 h.**	**22 h.**	**23 h.**	**24 h.**
Direction	N. 19° W	N. 22° W	N. 36° W	N. 80° W.	S. 78° W.	S. 69° W.	S. 50° W.	S. 44° W.
Speed (m. p. s.)	2.5	1.9	1.2	0.5	0.2	0.4	0.5	0.6

2. The land breeze is well marked from midnight to 10 a. m., and the sea breeze from 1 p. m. to 7 p. m., with transition periods between. The land and sea breezes do not blow at right angles to the shore line but are inclined to it.

3. The sea breeze is stronger than the land breeze, the speed of the former being 3 m. p. s., while that of the latter is 1.9 m. p. s.

4. No marked influence of high or low tide was noted nor was the velocity of the sea breeze greater on a rising than on a falling tide.

5. Sounding-balloon observations made on 31 clear days give means as follows:

TABLE 2.—*6:30 a. m.*

Elevation (meters)	0	100	200	300	400	500	600	800
Direction	S. 22° E.	S. 7° E.	S.	S. 25° E.	S. 38° E.	S. 51° E.	S. 73° E.	S. 79° E.
Speed (m. p. s.)	0.9	1.5	1.5	1.5	2.1	2.5	3.2	3.5

Elevation (meters)	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Direction	S. 89° E.	N. 84° E.	N. 54° E.	N. 29° E.	N. 25° W.	N. 15° W.	N. 32° W
Speed (m. p. s.)	3.3	2.7	2.7	1.0	1.7	1.8	3.5

TABLE 3.—*1 p. m.*

Elevation (meters)	0	100	200	300	400	500	600	800
Direction	N. 31° W.	N. 39° W.	N. 34° W.	N. 25° W.	N. 7° W.	N. 27° E.	N. 70° E.	E.
Speed (m. p. s.)	2.3	1.2	1.2	1.2	0.8	0.6	0.7	1.6

Elevation (meters)	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Direction	S. 87° E.	S. 32° E.	S. 10° E.	S. 25° W.	N. 83° W.	N. 68° W.	N. 53° W.
Speed (m. p. s.)	0.9	1.5	0.9	0.4	1.5	2.7	3.5

From these tables it will be seen that land and sea breezes up to an altitude of 400 meters maintain practically the same direction as at the surface. The wind direction above turns counter clockwise with ascent in the morning and clockwise in the afternoon. The alternation of the land and sea breeze completely disappears at 1,000 meters, but still higher the turning of the wind counterclockwise in the morning and clockwise in the afternoon is observed. The directions are opposite at 2,500 meters and become the same again at 4,000 meters.—*R. H. W.*

THE SEA BREEZE ON THE COAST OF CATALONIA.

[Sobre los vents estivals de conveccio a la costa Catalana, per Eduard Fontseré, Profesor a la Facultad de Ciencias de Barcelona, Director de la Estacion Aerológica. Barcelona, 1918.]

Amongst the numerous meteorological phenomena of which the general principles are known but the details vague, land and sea breezes occupy a leading place. No adequate study of the subject has been made in this country [British Isles], and Prof. Fontseré's memoir, which is devoted to the winds of the Spanish coast of the Mediterranean, may be welcomed as showing the right line of investigation. A large number of observers were found who collaborated in keeping records of the wind throughout day and night, noting the strength and direction every few hours and also the times of onset of the land and sea breezes and other salient changes. By combining the information collected from these observers with the results of the observations at the aeronautical station an adequate picture of the air movements could be constructed.

Although the prevailing upper currents across the coast in summer are from northwest, the land breeze is not developed with the same regularity as the sea breeze. On the coast line the sea breeze reaches its maximum strength about 13h. and it gradually works its way inland, the maximum at 30 kilometers or so from the coast occurring at 17h. The maximum sea breeze comes from the south, making an angle of about 45° with the shore, and the return current (in the layer from 1,000 to 3,000 meters) is from the west, so that the air tracks are flattened helices some 50 kilometers wide and 3 kilometers high. The ascending part of each helix is indicated by cumulus cloud, near the coast at midday, farther inland toward evening. Prof. Fontseré's work is provided with maps and diagrams which "talk" and would repay careful study.—*Met. Off. Circ. 34, Apr. 1, 1919, p. 4.*

LAND AND SEA BREEZES AT SIERRA LEONE.

[Met. Off. Circ. 3, Aug. 21, 1916, p. 4.]

The following figures, compiled from the original returns, show how different the prevailing winds at Sierra Leone are in the morning and evening:

	9h.			17h.		
	Frequency of winds from—					
	NE., E., SE.	W., SW.	Calms, etc.	NE., E., SE.	W., SW.	Calms, etc.
Winter, 90 days (Dec.–Feb.)	54	4	22	1	46	43
Spring, 92 days (Mar.–May)	52	27	13	1	65	
Summer, 92 days (June–Aug.)	30	31	31	1	58	
Autumn, 91 days (Sept.–Nov.)	53	13	25	0	66	25

THE FIRST SUCCESSFUL NON-STOP TRANS-ATLANTIC FLIGHT.

Within less than a month after the successful crossing of the Atlantic by the NC–4 a non-stop flight direct from Newfoundland to Ireland was made by Capt. John Alcock, pilot, and Lieut. Arthur W. Brown, navigator, of the British Royal Air Force. The Newfoundland coast was crossed at 5:28 p. m., Greenwich meridian time, June 14, and the Irish coast at 9:25 a. m., June 15, the entire distance of 3,040 kilometers, or 1,890 statute miles, having thus been traversed in practically 16 hours. If we assume that there were few deviations from a great circle course and that little time was lost in changing altitude, it appears that on the average an actual speed of about 53 m. p. s., or 118.5 m. p. h., was maintained.

Wind conditions for the flight were very nearly ideal, for not only did they furnish an average assistance of approximately 12 m. p. s., 25 to 30 m. p. h., but their direction was such (see Charts X and XI) as to enable the aviators to keep their machine true to course in spite of the handicap due to inability to check that course by means of observations. The weather, aside from the wind, was most unfavorable, as indicated in the published reports of the aviators. We quote from *Nature*, London, June 19, 1919, p. 306:

"Clouds were met at all altitudes (including dense fog in the lower levels) and it was generally impossible to see either ocean or sky. At the higher altitudes the machine became covered with ice, and at one time the air-speed indicator became clogged. The sense of horizontality was for the time lost, and the machine executed various evolutions until it had fallen so low that the sea became visible, and Capt. Alcock was able to recover a normal attitude.

"Only four observations of position were taken during the flight, these being made with reference to the sun, the moon, the pole star and Vega, respectively. All ships were warned that the flight was taking place, and asked to wireless their positions, but the aviators received no messages to guide them, and were entirely dependent on their own scanty observations.

"The average altitude was about 4,000 feet, but attempts were made to find better atmospheric conditions at various altitudes up to 11,000 feet without success."

From the foregoing it is evident, as has been stated elsewhere, that wind assistance is of prime importance. In the absence of radio reports from ships at sea and of observations with greater frequency than were made it would have been practically impossible to steer the correct course that was maintained without winds almost exactly parallel to that course. Moreover, the experience of Alcock and Brown, as well as that of the NC planes, Hawker and Grieve, and more recently the British dirigible R 34, shows that days with favorable weather for observational purposes are rare indeed, at least for any considerable portion of the journey. Hence a flight, if started during adverse wind conditions, is almost certain to meet with failure, until more efficient radiodirectional apparatus is perfected or until aircraft are produced of such speed as to be relatively independent of winds that are ordinarily encountered. —*W. R. Gregg.*

OCEAN WEATHER REPORTS AND FORECASTS FOR AVIATORS.

The Times announces over the signature of Admiral J. F. Parry, hydrographer of the navy, that in view of the extent to which aircraft will have to rely for information as to weather conditions upon data from ships at sea, the Admiralty have issued a notice to mariners making arrangements for a new and comprehensive scheme. This involves the collection by wireless of meteorological data from ships in all parts of the world and at the same time the organization of free transmission of weather bulletins from a sufficient number of wireless stations to admit of ships being constantly supplied with reliable weather reports and forecasts wherever they may be.

Six or eight observation stations are being established in the northeastern Atlantic and ships are asked to supply to them information regularly at 1 a. m., 7 a. m. and 1 p. m. (Greenwich meridian time) each day, besides sending additional messages when required to do so from areas in which peculiar conditions obtain. All ships fitted with the necessary apparatus will be called upon to assist, but on receipt of an intimation that another ship in the vicinity is reporting no message will be sent. This avoids not only duplication, but interference, a very necessary precaution with wireless telegrams. The technical difficulties of securing priority of transmission are considerable, but they can be overcome by cooperation. Should it prove impossible to decipher long-range telegrams, international "silent periods" might possibly have to be resorted to, but it is hoped that this may be avoided. Earnest endeavors are being made to secure international agreement in the matter of codes, signals, times, and methods in general.

The organization which has been undertaken by the Meteorological Office involves the collection of observations by code messages, at Valencia and Malin. The data will then be transmitted to London by wireless for coordination. Wireless bulletins will be issued, and may include either a weather report, that is an official statement of existing conditions in some particular area, or a weather forecast of the probable weather conditions, or both. A list is given of 42 wireless transmission stations in all parts of the world from which bulletins will be issued regularly. There are in addition certain other stations which will be available for the supply of information on demand. The British stations proposed are Poldhu, in Cornwall, and Cleethorpes, in Lincolnshire, both of which will shortly be ready for the purpose.

Quite apart from the enormous advance in the economic utilization of modern weather forecasting, the scheme holds almost boundless possibilities for the development of scientific meteorology, and we look forward with the highest hopes to the fruition of so important a scheme of co-operative effort.—*Symons's Met'l. Mag., London, May, 1919, p. 38.*

NEW WORLD'S AIRPLANE ALTITUDE RECORD.

Sublieutenant Cazale, of the French Air Service, who established on June 7 a new world's altitude record by reaching an altitude of 9,500 meters (31,160 feet), broke his own record on June 14 by climbing 10,100 meters (33,136 feet) in 55 minutes. Roland Rohlfs, on July 30, 1919, at Roosevelt Field, L. I., reached an altitude of 30,700 feet [9,357 meters], finding there a temperature of —25° F. and a wind of 100 mi/hr.—*Aviation and Aeronautical Engineering, July 1 and Aug. 15, 1919, pp. 594 and 84.*

Cazale's record closely approaches the highest ascents of men in balloons. In 1901, Berson and Süring reached a known height of 10,500 meters (and probably reached 10,800 meters), both being unconscious at the maximum height. In 1862, Glaisher and Coxwell may have reached the height of 11,200 meters; but Glaisher was unconscious for a period of about 13 minutes, and the observations were uncertain.—*McAdie, Principles of Aerography, 1917, pp. 10–11.*

A NEW RECENSION OF ARISTOTLE'S METEOROLOGY.[1]

Prof. Fobes's new text of Aristotle's Meteorology is a welcome addition to the little group of books, more or less (generally less) accessible to the modern meteorologist, whereby one may take stock of the progress that has been achieved in the study of the atmosphere since this study was elevated to the rank of a science by the Greek philosophers—above all, by Aristotle himself. Only a few of these books need be mentioned here. Of Aristotle's Meteorology the standard Greek text, prior to the appearance of the one here under review, was Bekker's; collated from four manuscripts and published by the Berlin Academy in 1831. In 1834–1836 appeared J. L. Ideler's revision of Bekker's text, accompanied by a new Latin translation, annotated extracts from the Greek commentaries of Alexander, Olympiodorus, and Philoponus, a very erudite Latin commentary by Ideler himself, and other relevant material—a monumental work. In 1863 was published J. Barthélemy Saint-Hilaire's French translation of the Meteorology, with introduction and copious explanatory notes. This is the only fairly accessible translation of the Meteorology in a modern language, and is therefore of unique interest to meteorologists who do not read Greek or Latin with facility. It is true that there are two English versions, viz, by Pargiter (1745) and Taylor (1812), but copies of them, especially the former, are exceedingly rare. Neither is represented in the Weather Bureau Library or in the Library of Congress. There are also two rare Italian versions, or paraphrases, both of the sixteenth century. An Italian translation by Aldo Mieli was announced for publication a few years ago, but has not yet appeared, so far as known to the present reviewer. Lastly, it is planned to include a translation of the Meteorology in The Works of Aristotle Translated into English, now in course of publication by the Clarendon Press, but, sad to say, E. W. Webster, who had this translation in hand, was one of the many young English scholars who laid down their lives in the recent war. A first-rate English version of this venerable work, especially one with comments from the standpoint of modern science, would fill a serious gap in the meteorological literature of our language. Meanwhile, a handy compend is, fortunately, furnished by T. E. Lones's Aristotle's Researches in Natural Science (London, 1912), of which Chapter III deals with meteorology.

As to other works presenting the views of the ancient Greeks on meteorological subjects, it need only be mentioned here that Ideler's Meteorologia Veterum Graecorum et Romanorum (Berlin, 1832) has now been advantageously replaced, so far as the Greeks are concerned, by the well-nigh exhaustive treatise of Otto Gilbert, Die meteorologischen Theorien des Griechischen Altertums (Leipzig, 1907).

[1] Aristotelis meteorologicorum libri quattuor recensuit indicem verborum addidit F. H. Fobes. Cantabrigiae Massachusettensium e typographeo academiae Harvardianae. 1918. xlviii, 236 p. 8°.

Prof. Fobes's edition of the Meteorology is designed purely as a contribution to classical scholarship. To the meteorologist and the student of meteorological history it will be interesting primarily as furnishing an authoritative Greek text resulting from the careful collation of all existing manuscript material, and secondarily as supplying, through its nearly exhaustive "index verborum," a better concordance to Aristotle's work than has hitherto been available. The introduction and footnotes deal exclusively with textual matters, especially *variæ lectiones*.

The typography—a delight to the eye—reflects the highest credit on the Harvard University Press.—*C. F. Talman.*

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*LORD RAYLEIGH, METEOROLOGIST.**

[1842–1919.]

The death of Lord Rayleigh, June 30, 1919, was a loss to the human race. For half a century he continuously added, in a measure that few have ever equaled, to our knowledge of nature, and thereby profoundly benefited every civilized being, not alone of his own day and generation but alike of all time to come. Modern industry, modern prosperity, and indeed all that constitutes modern civilization, rest in large measure on the work of only a few men of transcendent genius, and of these Lord Rayleigh was one of the greatest.

His hundreds of papers cover nearly every field of physics; and many of them also extend far over into the realms of other sciences. It is two groups of these papers of double or, rather, of multiple interest that are the special occasion for this note, namely, those that concern the light of the sky, and those that deal with the composition of the atmosphere.

Sky colors.—The fact that the sky usually is blue, but occasionally violet, green, yellow, or red, has of course been known since there were eyes to see, or at least since eyes first became color sensitive. Many ingenious speculations were offered in explanation of these phenomena, but each was a worse failure, if possible, than its hopelessly inadequate predecessor, until in 1871 Lord Rayleigh explained them so completely and so clearly that the problem was at once, and still is, regarded as solved in all essentials.

Sky polarization.[1]—It had also long been known that the light of the sky was partially polarized according to certain more or less definite laws, but this too was without explanation until Lord Rayleigh in his masterly paper on sky colors showed how, why, and to what extent, the light of the cloudless sky must always be polarized.

Composition of the atmosphere.—For more than a generation it has been confidently believed that the composition of the atmosphere was known even to mere traces, when in 1892 Lord Rayleigh showed that his belief was not well founded. He first showed that the "nitrogen" of the air was not the same as the nitrogen of chemical compounds; and then, working jointly with Ramsay, soon separated from the atmosphere a hitherto unknown gas, argon, that amounts to nearly 1 per cent of the whole by volume, and much more than 1 per cent by weight. A quantity, therefore, of decided importance since its 200 pounds for every square yard of the earth's surface is perhaps twice as great as the average amount of water vapor.

The stimulus of the discovery of argon led at once to a searching examination of the atmosphere, and the discoveries in it of several other gases of the argon, or inert, family—helium, neon, krypton, and zenon.

Other studies.—In addition to the above three fundamental contributions to meteorology, Lord Rayleigh also made important additions to our knowledge of the vibrations of the atmosphere as a whole, with their relation to certain barometric changes; of stellar scintilation; of atmospheric refraction; and of the dynamics of revolving fluids.

These, then, are the many and more than sufficient reasons for writing "Lord Rayleigh, meteorologist."—*W. J. H.*

* Three other obituaries, are published in *Nature* (London), July 10, 1919, pp. 365-369.

[1] For an excellent review of Lord Rayleigh's papers on the color and polarization of sky light, see MONTHLY WEATHER REVIEW, Sept., 1900, 28:382.

RICHARD H. CURTIS.

[1847–1919.]

By the death of Mr. Richard H. Curtis on May 21 meteorology has lost one who took a keen interest in its various branches for more than half a century. Mr. Curtis entered the meteorological department of the board of trade under Admiral FitzRoy in 1861. For a long time he prepared for the press the results of the work of observatories, and in 1907 he became superintendent of the instruments and observatories division of the office. * * * He retired from the meteorological office in 1912 at the age of 65, but continued to supply anemometric records to the office and rainfall records to Symons's Meteorological Magazine until a few months ago. * * * Mr. Curtis contributed many papers to the [Quarterly] Journal [of the Royal Meteorological Society] on various subjects, and especially on sunshine and wind force. He introduced an improvement in the mounting for the lens and bowl of the Campbell-Stokes sunshine recorder, and carried out interesting experiments on the distribution of wind pressure upon flat surfaces. He also aided in working up the atmospheric effects of the Krakatoa eruption of August, 1883, the results of which were incorporated in the report by the Royal Society.—*Nature (London), May 29, 1919, p. 250.*

UNIFICATION OF THE ASTRONOMICAL WITH THE METEOROLOGICAL DAY.

"It is announced that in the Nautical Almanac for 1925, the day is to be considered as beginning at midnight so as to make the astronomical day agree with the civil day. * * *

"It appears that this step is being taken chiefly in the interests of seamen but meteorologists will also welcome it because the agreement thus achieved between the astronomical and the meteorological day removes the possibility of confusion in stating the dates of observations. For many years the observers in astronomical observatories have used the two systems side by side but earlier records are to be found in which meteorological events are reckoned by astronomical time."—*Meteorological Office Circular 36, June 2, 1919, p. 1.*

FURTHER NOTE ON THE HURRICANE OF AUGUST 6, 1918.*

By R. A. DYKE, Meteorologist.

[Dated: Weather Bureau, New Orleans, La., May 16, 1919.]

The accompanying barograph and thermograph traces (figs. 1 and 2) for the period August 5 to 11, 1918, at Sulphur, La., were furnished by Mr. P. K. Kelley of Sulphur, which was slightly west of the path of the center of the West Indian hurricane.

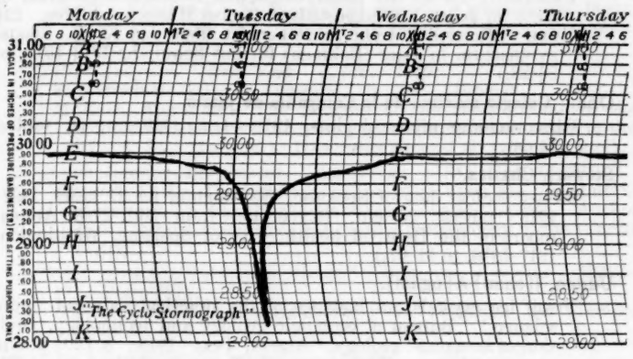

FIG. 1.—Barograph trace at Sulphur, La., during the passage of the August, 1918 hurricane.

In order to reduce the readings to sea level the barogram was compared with the barometer at Port Arthur, Tex. The correction was 0.03 inch. The instrumental error was found to be 0.15 inch, giving a total correction of 0.18 inch. There are no means of determining the instrumental error at the time of the lowest reading during the storm, but assuming the same ratio as for readings near the normal, the extreme minimum sea-level pressure was 28.36 inches, a remarkably low reading. This occurred at about 2 p. m., 90th meridian time.

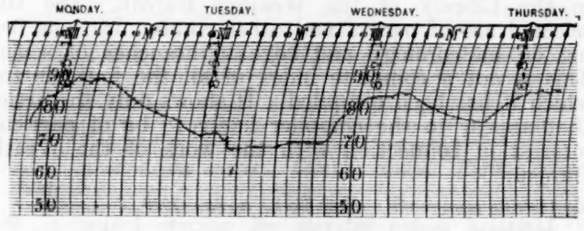

FIG. 2.—Thermograph trace at Sulphur, La., during the passage of the August, 1918, hurricane.

The extreme abruptness of the pressure fall and subsequent rise confirm the reports to the effect that the storm was of small diameter, very intense, and moving rapidly.

PANAMA RAINFALL.

Mr. H. G. Cornthwaite, chief hydrographer, Canal Zone, sent us the accompanying map of the distribution of average annual rainfall in Panama. Unfortunately, it was received too late to be included with his article on Panama rainfall published in the MAY REVIEW, pages 298–302.—ED.

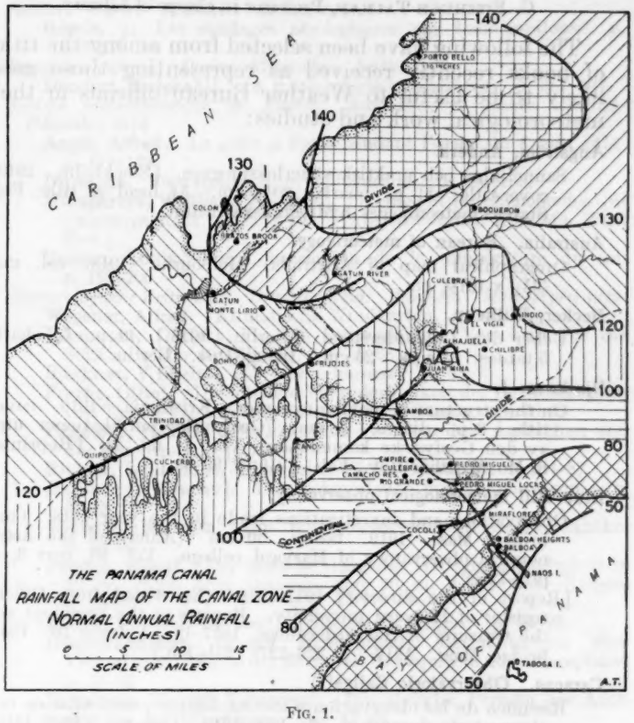

FIG. 1.

CORRIGENDA.

This REVIEW, May, 1919:

Page 298, tenth line of synopsis, "91.61" *should read* "68.44."

Page 301, second column, twenty-first line, "freshets" *should read* "floods."

Page 301, Table 1, Empire, maximum rainfall for one hour, *for* "Oct. 21, 1908" *read* "Oct. 21, 1918."

PANAMA CLOUD PHENOMENA.

The rainy season, which started about a month ago, restricts flying somewhat in the Panama Canal Zone. With it came the most unusual cloud formations. They settle on the earth's surface, and it matters not how high an aviator goes there are always more clouds above. At 20,000 feet the cloud canopy exists, and the moisture does not, during the summer, freeze as in the latitude 30° or higher. It is not a dense formation, neither is it a series of layers at different levels, such as usually found. Ordinarily there is a great deal of clear space with these clouds of various sizes, shapes, and density, scattered here and there and at any and every altitude. Then, most unusual of all, once in a while you will find a cloud going right straight up an indefinite distance into the heavens, a vertical column of cloud, which generally tapers slightly with increasing altitude.—*From Aeronautics, London, July 31, 1919, p. 114.*

* A report of this storm will be found in the MONTHLY WEATHER REVIEW, Aug., 1918, 46:379.

BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Ångström, Anders.

Sannolikhet och praktisk väderleksprognos. [Stockholm. 1919.] cover-title. 11 p. charts. 20½ cm. At head of title: Från Statens meteorologisk-hydrografiska anstalt.

Australia. Bureau of meteorology.

Orographical map of Australia. Melbourne. 1918. col. map 76½ x 101½ cm.

Becker, Wilhelm.

Ueber den Luftwiderstand. [Berlin. 1913.] 49 p., l., charts 5 tables. diagrs. 23 cm. Inaug.-Diss. Berlin.

Bjerknes, J.

On the structure of moving cyclones. Kristiania. 1919. cover-title. 8 p. diagrs. 31 cm. (Geofysiske publikationer utgit av den Geofysiske kommission. Vol. 1, no. 2.) [Reprinted in Mo. Weather Rev., Feb., 1919, p. 95–99.]

Blue Hill meteorological observatory.

Observations and investigations made in the year 1918. Cambridge, Mass. 1919. tables. 30 cm. (Annals of the Astronomical observatory of Harvard college. Vol. 83, part 3, p. [97]–125.)

[Report of the director] 1917–1918. (Excerpted from Official register of Harvard university. Reports of the president and the treasurer of Harvard college, 1917–18. Volume 16. Cambridge, Mass. 1919. p. 226–227. 23½ cm.)

Caracas. Observatorio Cajigal.

Resumen de las observaciones meteorológicas practicadas en este observatorio durante el año 1908–1918. Caracas. [1909–1919.] 11 sheets. various sizes.

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Observações meteorológicas, magnéticas e sísmicas feitas no ano de 1918. Volume 57. Coímbra. 1919. viii, 165 p. tables. 36½ cm.

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L'influence du reboisement sur l'abondance des eaux. [2] p.26, cm. (Extrait de la "Revue scientifique" du 24 août 1918.) At head of title: Association centrale pour l'aménagement des montagnes. Office de défense forestière et pastorale. . .

Eredia, Filippo.

Sulla direzione delle correnti aeree in Sicilia. Roma. 1918. cover-title. tables. 28 cm. At head of title: Rendiconti della R. Accademia dei Lincei. Classe di scienze fisiche, matematiche e naturali. Estratto dal vol. 27, serie 5a, 2° sem., fasc. 6.°, p. [171]–175.)

Exner, Felix M.

Dynamische Meteorologie. Leipzig. 1917. ix, 308 p. charts. diagrs. 23 cm.

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Great Britain. Meteorological office.

The climate of the Balkans, Greece, and the Aegean Sea during the winter months. London. 1915. 34 p. tables. 24½ cm M. O. 226.

Koestler, W.

Blitzgefahr und Blitzschutz; insbesondere die Bedeutung, Funktion und Konstruktion vom Gebäude-Blitzableiter . . . Burgdorf. 1914. vii, 111 p. illus. diagrs. 19 cm.

Krauss, Joseph.

Grundzüge der maritimen Meteorologie und Ozeanographie. Mit besonderer Berücksichtigung der Praxis und der Anforderungen in Navigationsschulen. Berlin. 1917. xii, 221 p. illus. charts, tables. 21 cm.

Maracaibo. Estación [meteorológica].

Resumen de las observaciones, 1° de marzo, 1915–31 de diciembre, 1918. Maracaibo [1916–1919]. 4 sheets. various sizes. At head of title: Red meteorológica de Venezuela.

Merida. Estación [meteorológica].

Resumen de las observaciones practicadas, 1° de mayo, 1915–31 de diciembre de 1918. Merida. [1916–1919] 4 sheets. various sizes. At head of title: Red meteorológica de Venezuela.

Michl, Anton.

Uebersicht der an der meteorologischen Beobachtungsstation in Eger im Jahre 1912 angestellten Beobachtungen. tables. 23½ cm. (Excerpted from Jahresbericht über das K. K. Staatsgymnasium in Eger (Bohmen) für das Schuljahr 1912–1913, p. 26–28.)

Oña. Colegio máximo de la Compañia de Jesús.

Observaciones meteorologicas, 1918. Ona 1919. n. p. tables. 24 cm.

Stewart, Charles.

Meteorological data of Spokane, Washington, for 37 years, 1882–1918. tables. 23 cm. (Excerpted from 26th–27th Annual report of the Dept. of health, City of Spokane, Washington, 1917–1918, p. 91–97.)

Udden, J[ohan] A[ugust].

Fossil ice crystals, an instance of the practical value of "pure science." Bureau of economic geology and technology, Division of economic geology. Austin, Tex. 1918. 8, [20] p. 10 plates. 23 cm. (University of Texas bulletin. no. 1821. April 10, 1918.)

Ugueto, Luis.

Climatología de Caracas en los ultimos 27 años. Caracas. 1918. cover-title. 625–650 p. charts. tables. 31 cm. Running title: Documentos de la memoria de instruccion publica.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Engineering news-record. New York. v. 83. 1919.

Lightning pushes sidewalk off concrete bridge. p. 68–69. (July 10.)

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SPECIAL OBSERVATIONS.

HALO PHENOMENA OBSERVED DURING JUNE, 1919.

By WILLIS RAY GREGG, Meteorologist.

Station.	Altitude.	Latitude.	Longitude.	Date.	Form observed.	Time of—		Theodolite readings.					
						Beginning.	Ending.	Time.	Radius inside.	Radius outside.	Length of arc.	Distance from sun or moon.	Altitude of sun or moon.
	m.	° ′	° ′						°	°	°	°	°
Broken Arrow, Okla.*	233	36 02	95 49	8	Circumzenithal arc	7:00 a. m.	7:14 a. m.	7:12 a. m.			7		22.6
				19	Solar halo, 22°	2:45 p. m.	3:00 p. m.						
				24	Solar halo, 22°	6:40 p. m.	7:30 p. m.						
				24	Parhelion, 22°, right	6:40 p. m.	7:30 p. m.						
				24	Parhelion, 22°, left	6:40 p. m.	7:30 p. m.						
Canton, N. Y.	137	44 36	75 10	12	Lunar halo, 22°	10:00 p. m.							
				13	Solar halo, 22°	10:00 a. m.	11:30 a. m.						
				24	Solar halo, 22°	2:10 p. m.	3:00 p. m.						
				30	Solar halo, 22°	7:40 a. m.	11:00 a. m.						
Cincinnati, Ohio	191	39 06	84 30	19	Parhelion, 22°, left	5:54 p. m.	5:58 p. m.						
Dayton, Ohio	274	39 46	84 10										
Drexel, Nebr.*	396	41 20	96 16	2	Solar halo, 22°	3:05 p. m.	4:10 p. m.	3:15 p. m.	22	23	180		47
Ellendale, N. Dak.*	444	45 59	98 34	3	Solar halo, 22°	11:45 a. m.	12:55 p. m.	12:36 p. m.	21.5	22.5	360		66
				14	Solar halo, 22°	10:30 a. m.	1:15 p. m.						
				15	Solar halo, 22°	6:45 a. m.	8:10 a. m.						
				26	Solar halo, 22°	6:30 a. m.	7:15 a. m.	7:05 a. m.	22	23	190		
Groesbeck, Tex.*	141	31 30	96 28	9	Solar halo, 22°	1:07 p. m.	2:42 p. m.	1:19 p. m.	21.5	23.5	360		74.5
Leesburg, Ga.*	85	31 47	84 14	2	Solar halo, 22°	2:50 p. m.	3:10 p. m.	2:50 p. m.	22		110		
				8	Lunar halo, 22°	8:45 p. m.	D. n. p. m.	9:00 p. m.	22		270		
				11	Solar halo, 22°	11:55 a. m.	12:10 p. m.	12:05 p. m.	22		180		
				11	Lunar halo, 22°	8:30 p. m.	D. n.	8:40 p. m.	22		290		
				12	Solar halo, 22°	3:20 p. m.	5:40 p. m.	3:25 p. m.	22		320		40
				12	Parhelion, 22°, right	5:23 p. m.	5:38 p. m.	5:31 p. m.				225	19
				12	Parhelion, 22°, left	5:23 p. m.	5:40 p. m.	5:30 p. m.				23	19
				13	Solar halo, 22°	2:47 p. m.	2:50 p. m.	2:47 p. m.	22		270		
				17	Solar halo, 22°	3:56 p. m.	4:10 p. m.	3:56 p. m.	22		150		
				19	Solar halo, 22°	7:05 p. m.	7:15 p. m.	7:10 p. m.	22		180		32
				20	Solar halo, 22°	6:30 a. m.	6:50 a. m.	6:35 a. m.	22		180		
				20	Lunar halo, 22°	12:30 a. m.	D. n. a. m.	12:30 a. m.	22		180		
				26	Solar halo, 22°	12:00 m.	12:30 p. m.	12:04 p. m.	22		360		78
				26	Solar halo, 22°	6:50 a. m.	7:20 a. m.	6:55 a. m.	22		90		
				28	Solar halo, 22°	7:38 a. m.	7:50 a. m.	7:40 a. m.	22		65		
Madison, Wis.	297	43 05	89 23	7	Solar halo, 22°	6:25 p. m.	6:40 p. m.						
				9	Solar halo, 22°	4:24 p. m.	5:00 p. m.						
				10	Solar halo, 22°	8:15 a. m.	1:00 p. m.						
				11	Solar halo, 22°	5:45 a. m.	6:30 a. m.						
				11	Solar halo, 22°	9:30 a. m.	12:00 m.						
				14	Solar halo, 22°	2:30 p. m.							
				15	Solar halo, 22°	3:15 p. m.	6:10 p. m.						
				16	Solar halo, 22°	7:20 a. m.	2:00 p. m.						
				16	Parhelion, 22°, left	6:40 p. m.	6:48 p. m.						
				21	Solar halo, 22°	6:30 a. m.	8:00 a. m.						
				30	Solar halo, 22°	1:00 p. m.	4:00 p. m.						
Nashville, Tenn.	166	36 10	86 47	25	Solar halo, 22°	3:30 p. m.	4:15 p. m.	3:45 p. m.					
Royal Center, Ind.*	225	40 53	86 29										
Tatoosh Island, Wash.	26	48 23	124 44	1	Solar halo, 22°	10:20 a. m.	4:30 p. m.						
				3	Solar halo, 22°	12:57 p. m.	4:50 p. m.						
				4	Solar halo, 22°	8:28 a. m.	9:00 a. m.						
				4	Parhelion, 22°, right	6:27 p. m.	6:35 p. m.						
				4	Parhelion, 22°, left	5:26 a. m.	5:30 a. m.						
				7	Solar halo, 22°	11:16 a. m.	11:30 a. m.						
				7	Solar halo, 22°	2:26 p. m.	7:00 p. m.						
				7	Parhelion, 22°, left	6:59 p. m.	7:00 p. m.						
				10	Solar halo, 22°	2:06 p. m.	3:00 p. m.						
				13	Solar halo, 22°	2:29 p. m.	7:10 p. m.						
				16	Solar halo, 22°	3:20 p. m.	7:15 p. m.						
				16	Parhelion, 22°, right	5:52 p. m.	7:10 p. m.						
				16	Parhelion, 22°, left	4:44 p. m.	5:07 p. m.						
				16	Upper tangent arc	4:44 p. m.	5:07 p. m.						
				16	Lower tangent arc	4:44 p. m.	4:50 p. m.						
				17	Solar halo, 22°	10:35 a. m.	7:55 p. m.						
				17	Parhelion, 22°, right	3:59 p. m.	7:15 p. m.						
				17	Parhelion, 22°, left	6:05 p. m.	7:15 p. m.						
				17	Upper tangent arc	3:55 p. m.	6:45 p. m.						
				17	Lower tangent arc	3:59 p. m.	4:30 p. m.						
				17	Circumscribed halo	2:00 p. m.	2:30 p. m.						
				17	Solar halo, 46°	3:20 p. m.	4:30 p. m.						
				17	Circumzenithal arc	6:05 p. m.	6:15 p. m.						
				17	Light pillar	7:35 p. m.	8:10 p. m.						
				18	Solar halo, 22°	5:20 a. m.	6:42 a. m.						
				18	Parhelion, 22°, right	5:26 a. m.	6:42 a. m.						
				18	Parhelion, 22°, left	5:26 a. m.	5:33 a. m.						
				18	Upper tangent arc	5:29 a. m.	5:33 a. m.						
				18	Light pillar	4:19 a. m.	4:50 a. m.						
				19	Solar halo, 22°	2:23 p. m.	3:00 p. m.						
				20	Solar halo, 22°	5:29 a. m.	12:30 p. m.						
				20	Parhelion, 22°, right	6:02 a. m.	8:30 a. m.						
				20	Parhelion, 22°, left	6:02 a. m.	8:30 a. m.						
				20	Upper tangent arc	9:25 a. m.	10:00 a. m.						
				24	Solar halo, 22°	8:48 a. m.	12:40 p. m.						
				24	Parhelion, 22°, right	8:48 a. m.	9:35 a. m.						
				24	Parhelion, 22°, left	8:48 a. m.	9:45 a. m.						
				24	Solar halo, 46°	8:48 a. m.	9:10 a. m.						
				24	Parhelic circle	8:48 a. m.	9:22 a. m.						
				24	Paranthelion, 120° right	8:48 a. m.	8:57 a. m.						
				24	Paranthelion, 120°, left	8:48 a. m.	8:57 a. m.						
				24	Solar halo, 22°	3:40 p. m.	7:05 p. m.						
				24	Parhelion, 22°, right	4:12 p. m.	7:05 p. m.						
				24	Parhelion, 22°, left	4:12 p. m.	7:05 p. m.						
				25	Solar halo, 22°	11:00 a. m.							
				25	Parhelion, 22°, right	7:04 p. m.							
				25	Parhelion, 22°, left	7:04 p. m.							
				26	Solar halo, 22°	8:51 a. m.	9:00 a. m.						
				27	Solar halo, 22°	1:31 p. m.	2:15 p. m.						
York, N. Y.‡	232	42 52	77 53	11	Solar halo, 22°	11:30 a. m.	2:00 p. m.	12:40 p. m.			360		
				29	Solar halo, 22°	11:30 a. m.	6:15 p. m.	12:30 p. m.			360		

*Aerological station.

‡ Taken at Rochester, N. Y.

Halo phenomena observed during June, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds.			Station. pressure.	Precipitation.	
				Amount.	Kind.	Direction.		Last previous ended.	First subsequent began.
Broken Arrow, Okla.*	8	B. G. Y. O. R.	Bright	Few. 4	Ci.St. St.Cu.	ssw.	Rising	D. N., a., 7th	7:04 a. m., 8th.
	19	R	Dim	Few.	Ci.St.	w.	Falling	11:25 a. m., 19th	11:33 a. m., 20th.
	24	R	Bright	3	Ci.St.	w.	Stationary	8:00 p. m., 23d	8:20 a. m., 26th.
	24	R	Bright						
	24	R	Bright						
Canton, N. Y.	12	R	Dim	3	Ci.St.	w.	Stationary	D. N., a., 10th	D. N., a., 15th.
	13	Y	Dim	2	Ci.	nw.	Falling	D. N., a., 10th	D. N., a., 15th.
	24	R	Dim	2	Ci. St.	w.	Falling	D. N., a., 23d	6:27 p. m., 25th.
	30	R	Dim	2	Ci.St	w.	Falling	D. N., a., 27th	4:42 p. m., 5th.
Cincinnati, Ohio	19		Dim	7	A. St.	ne.	Stationary	5.03 p. m., 17th	3.55 p. m., 21st.
Dayton, Ohio									
Drexel, Nebr.*	2	O. Y. G. B.	Bright	9	Ci. St.	s.	Stationary	D. N. a., 21st	8:12 p. m., 2d.
Ellendale, N. Dak.*	3	W	Dim	Few. 10	St. Cu. A. Cu.	n. se.	Falling	12:20 p. m., 1st	3:15 p. m., 3d.
	14		Dim				Falling	4:55 p. m., 11th	10:50 p. m., 17th.
	15		Dim	3 1	A. St. A. Cu.	s. s.	Stationary	4:55 p. m., 11th	10:50 p. m., 17th
	26	Y	Bright	9	A. St.	s.	Stationary	11:25 a. m., 21st	8:30 p. m., 1st.
Groesbeck, Tex.*	9	R. O. Y. G.	Dim	4	Ci. St.	w.	Falling	9:57 a. m., 9th	D. N., a., 10th.
Leesburg, Ga.*	2	R. O	Bright	2	St.	sw.	Stationary	1:45 p. m., 2d	5:45 p. m., 2d.
				2	A. St.	n.			
				7	St. Cu.	nne.			
	8	R	Dim	8	Ci. St.	nw.	Rising	6:30 a. m., 4th	10:07 a. m., 11th
				2	St. Cu.	ene.			
	11	R. O. Y. G.	Dim	2	A. St.	ne.	Stationary	10:12 a. m., 11th	2:51 p. m., 11th.
				8	Cu.	e.			
	11	R. Y.	Dim	7	A. St.	ne.	Stationary	3:01 p. m., 11th	D. N., a., 12th.
				3	St. Cu.	ne.			
	12	R. Y.	Dim	2	Ci. St.	ene.	Stationary	2:45 p. m., 12th	6:49 p. m., 12th.
				3	A. St.	ene.			
	12	R. Y.	Dim	6	A. St.	ne.	Stationary	2:45 p. m., 12th	6:49 p. m., 12th.
	12	R. Y.	Dim	4	St. Cu.	ne.			
	13	R	Dim	7	Ci. St.	w.	Falling	7:38 p. m., 12th	6:15 p. m., 15th.
				2	Cu.	ene.			
	17	R	Dim	4	A. St.	nw.	Stationary	5:36 p. m., 16th	D. N., p., 17th.
				Few.	Cu.	se.			
	19	R. O. G.	Bright	3	Ci. St.	nw.	Stationary	D. N., a., 18th	6:16 p. m., 19th.
				3	A. Cu.	e.			
	20	R	Dim	5	Ci. St.	n.	Stationary	6:25 p. m., 19th	
				4	A. Cu.	n.			
	20			10	A. St.		Stationary	6:25 p. m., 19th	
	26	R. O. Y. G.	Bright	2	Ci.	wnw.	Falling	7:10 p. m., 23d	5:37 p. m., 26th.
				2	Ci. St.	wnw.			
	26	R. Y.	Dim	2	Ci. St.	n.	Stationary	7:10 p. m., 23d	5:37 p. m., 26th.
				5	A. Cu.	n.			
	28	R. O.	Dim	4	Ci. St.	n.	Stationary	6:16 p. m., 27th	1:07 p. m., 28th.
				2	A. Cu.	nw.			
Madison, Wis.	7		Bright	4	Ci. St.		Rising	5:15 p. m., 7th	11:30 p. m., 9th.
				6	St. Cu.				
	9	R	Faint	10	Ci. St.	w.	Falling	5:15 p. m., 7th	11:30 p. m., 9th.
	10		Bright	6	Ci. St.	w.	Stationary	D. N., a., 10th	4:52 p. m., 10th.
	11		Dim	4	Ci.	w.	Stationary	D. N., p., 10th	1:25 p. m., 11th.
				4	Ci. St.	w.			
	11		Bright	10	Ci. St.	w.			
	14		Bright				Stationary	1:33 p. m., 14th	5:24 a. m., 16th.
	15	R	Dim	2	Ci.	w.	Falling	1:35 p. m., 14th	5:24 a. m., 16th.
				5	A. St.	sw.			
	16		Bright	5	Ci. St.	w.	Stationary	6:20 a. m., 16th	5:25 p. m., 16th.
				3	Cu.	nw.			
	16		Bright	4	Ci. St.	w.		6:40 p. m., 16th	6:50 p. m., 16th.
				2	A. St.	w.			
	21			8	Ci. St.	w.	Stationary	5:20 p. m., 20th	9:15 p. m., 22d.
				2	A. St.	e.			
	30			8	Ci. St.	sw.	Stationary	3:33 p. m., 25th	12:35 p. m., 3d.
Nashville, Tenn	25	R. O. Y.	Bright	3	Ci. St.	w.	Stationary	8:45 a. m., 24th	4:20 p. m., 6th.
Royal Center, Ind.*				3	Cu.	w.			
Tatoosh Island, Wash	1	R. O. Y. B.	Bright	3	Ci. St.	w.	Falling	7:15 a. m., 29th	7:17 a. m., 2d.
				4	A. St.	w.			
	3		Dim	3	Ci.	w.	Falling	D. N., a., 3d	6:21 p. m., 8th.
				1	St.	w.			
	4	O	Dim	2	Ci.	w.	Falling	D. N., a., 3d	6:21 p. m., 8th.
				1	A. Cu.	w.			
	4	R. B	Dim	2	Ci.	w.			
	4	R. B	Dim	7	Ci. Cu.	w.			
				1	St.	w.			
	7		Dim	4	Ci. St.	nw.	Falling	D. N., a., 3d	6:21 p. m., 8th.
				1	A. St.	sw.			
	7	O	Dim	5	Ci. St.	nw.	Falling	D. N., a., 3d	6:21 p. m., 8th.
				1	A. St.	nw.			
	7	R. B	Dim	7	A. St.	w.			
	10	R. B	Dim	7	A. St.	nw.	Rising	12:10 p. m., 10th	D. N., p., 10th.
				2	St.	s.			
	13	R. O. B	Bright	4	Ci.	s.	Rising	6:40. a. m., 13th	5:40 a. m., 14th.
	16	O	Bright	4	Ci. St.	sw.	Rising	7:55 a. m., 14th	10:50 a. m., 19th.
				1	St. Cu.	sw.			
	16	R. O. Y. G. B. V. W.	Bright	Few.	Ci. St.				
	16	R. V	Dim	1	Ci. St.	w.			
				Few.	Cu.	sw.			
	16	O	Dim						
	16	O	Dim						
	17	R. O. Y. G. B. V.	Bright	9	Ci. St.	sw.	Rising	7:55 a. m., 14th	10:50 a. m., 19th
				Few.	Cu.	sw.			
	17	R. B.	Dim						
	17	R. B.	Dim	7	Ci. St.	sw.			
	17	O. V	Bright	8	Ci. St.	sw.			
				Few.	Cu.				
	17	Y	Dim						

* Aerological station.

† Beginning with part nearest sun or moon.

R, red; O, orange, etc.

Halo phenomena observed during June, 1919—Continued.

Station.	Date.	Colors.†	Degree of brightness.	Clouds. Amount.	Clouds. Kind.	Clouds. Direction.	Station pressure.	Precipitation. Last previous ended.	Precipitation. First subsequent began.
Tatoosh Island, Wash. (Continued)	17	Y	Dim						
	17	R. B	Dim	8 Few.	Ci. St. Cu.	sw.			
	17	R. B	Dim						
	17	Y	Dim	3 6	Ci. St. A. St.	sw. sw.			
	18	R. Y. B	Bright	3 1	Ci. St. Ci. Cu.	s. s.	Rising	7:55 a. m., 14th	10:50 a. m., 19th.
	18	R. B. W	Bright						
	18	R. B	Dim						
	18	Y	Dim						
	18	Y	Bright	3 5 5 4	Ci. St. A. St. A. St. St.	s. s. s. s.	Rising	1:55 p. m., 19th	11:20 a. m., 21st.
	19	O	Dim	8	Ci.	s.	Falling	1:55 p. m., 19th	11:20 a. m., 21st.
	20	R. O. Y. B	Bright						
	20	R. Y. B	Dim						
	20	R. O. Y. G. B. V	Bright	8	Ci. St.	s.			
	20	Y	Dim	9	Ci. St.	s.			
	24	R. O. Y. G. V	Bright	5	Ci. St.	w.	Falling	10:10 a. m., 23d	4:26 a. m., 25th.
	24	R. O. V	Bright						
	24	R. O. V	Bright						
	24	R	Dim						
	24	W	Bright						
	24	W	Dim						
	24	W	Dim						
	24	O	Dim	3	Ci.	w.	Falling	10:10 a. m., 23d	4:26 a. m., 25th.
	24	R. B. W	Dim	3	Ci.	w.			
	24	R. B. W	Dim						
	24	R. O. B	Bright	9 1 4	A. St. St. Ci.	w. w. s.	Rising	5:25 a. m., 25th	10:15 a. m., 28th.
	25	R. Y. G. V	Bright	1	St. Cu.	w.			
	25	R. Y. G. V	Bright						
	26	O	Dim	2 5	Ci. St. Cu.	s. s.	Rising	5:25 a. m., 25th	10:15 a. m., 28th.
	27	R. B	Dim	7	A. St.	sw.	Falling	5:25 a. m., 25th	10:15 a. m., 28th.
York, N. Y.‡	11	R. Y	Brilliant	10	Ci. St.	nw.	Falling	1:00 p. m., 9th	4:15 p. m., 16th.
	29	R. O. Y	Brilliant	8	Ci. St.	w.	Stationary	D. N., a., 27th	5:00 p. m., 5th.

† Beginning with part nearest sun or moon. R, red; O, orange, etc. ‡ Taken at Rochester, N. Y.

MONTHLY PUBLICATION OF HALO PHENOMENA TO BE DISCONTINUED.

The foregoing table completes one year's record of halo phenomena, as observed at several well-distributed stations in the United States. In addition to a tabulation of the different forms noted, there have been included such angular measurements as could be made by means of theodolites at the six aerological stations. The purpose of this study, as outlined in the MONTHLY WEATHER REVIEW for July, 1918, pages 309–310, is to obtain a long series of reliable data from which it will be possible to determine the seasonal and latitudinal distribution of the different halo forms and to add to our knowledge concerning angular measurements, relation to types of pressure distribution, precipitation, etc. It was thought that the study should continue at least three, preferably five, years, and it was expected that brief summaries would be published in the MONTHLY WEATHER REVIEW. The continuance of this latter procedure has been found impracticable, however, owing to the large amount of data received for the limited space available in the REVIEW. In the future, therefore, the data will not be published, but they will be tabulated as heretofore at the Central Office and, when a sufficient period of observation has been covered, a general summary will be issued. It is hoped that the enthusiasm heretofore shown by the observers in this work may continue, in order that we may have as complete records as possible of "these attractive and interesting optical phenomena."—*W. R. Gregg.*

NOTES.

Mr. C. O. Schick, of the Groesbeck, Tex., Aerological Station, reports that on June 10, while traveling in northeast Texas, he observed from one side of the train a "complete and brilliant rainbow," and from the other side "a prismatically colored solar halo of [probably] 22° * * * with brilliant parhelia. * * * The arc of the halo consisted of two sections [of approximately 45° each]. The altitude of the sun was about 10° [90th meridian time]. * * * [As observed a little later] the attendant clouds were six-tenths stratus from the southeast and three-tenths cirro-stratus from the west."

UNUSUAL HALOS AT JUNEAU, ALASKA, JUNE 9, 1919.

By M. B. SUMMERS, Meteorologist.

[Dated Weather Bureau, Juneau, Alaska, June 16, 1919.]

A solar halo of unusual design that was observed at Juneau, Alaska, on the afternoon of June 9, 1919.

The phenomenon was first seen at 12 noon, 135th meridian time, at which hour it consisted solely of the ordinary 22° halo. The additional circles and arcs shown in figure 1 were not observed until 3 p. m., and reached their greatest brilliancy about 3:30 p. m. At that hour all markings in the drawing were fairly well defined except the inner oblique arcs of the anthelion, the left or northern one only being visible. The right, or southern, arc was not observed by the writer, but was seen by a re-

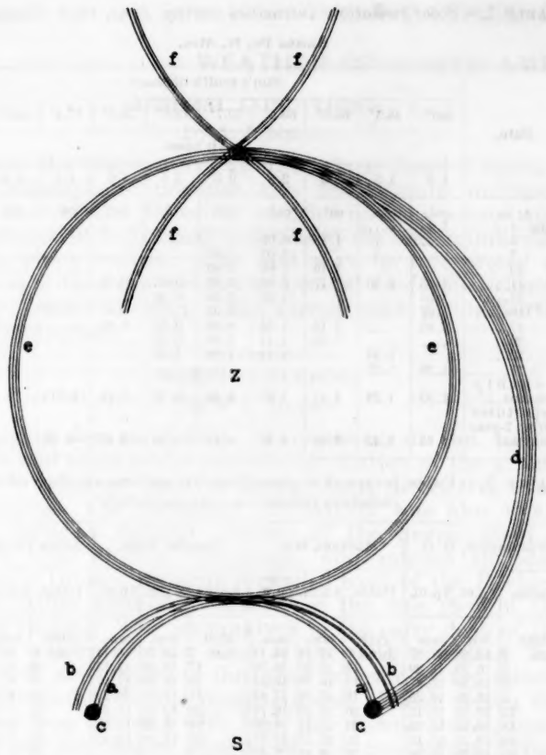

FIG. 1.—Solar halo, Juneau, Alaska, June 9, 1919, 3:30 p. m. *aa*, arc of halo of 22°, red on inside; *bb*, arc of circumscribed halo; *cc*, parhelia, 22°; d, parhelic circle: *ee*, apparently what Bravais calls a secondary parhelic circle, approximately 34° radius; *ff*, apparently oblique arcs of the anthelion.

liable observer a few minutes earlier. The only clouds visible were a thin veil of cirro-stratus, which almost disappeared by 4:30 p. m., leaving only a faint trace of the 46° arc. A little later, however, the cloud thickened and the halo was renewed with greater brilliancy than before, but in altered form and design, as shown in figure 2. The clouds in the northern half of the sky thickened rapidly after 5:30 p. m. and by 7:20 p. m. all traces of the halo had disappeared.

The halo of 46° was at times composed of white light and again of the prismatic colors, these being arranged with the red inside. The same arrangement obtained in the inner 22° halo, but in the circumzenithal arc, tangent to the 46° halo, the colors were reversed. The secondary parhelic circle of approximately 34° radius (fig. 1) was of indifferent color and not so well defined as the smaller and larger circles, but was nevertheless

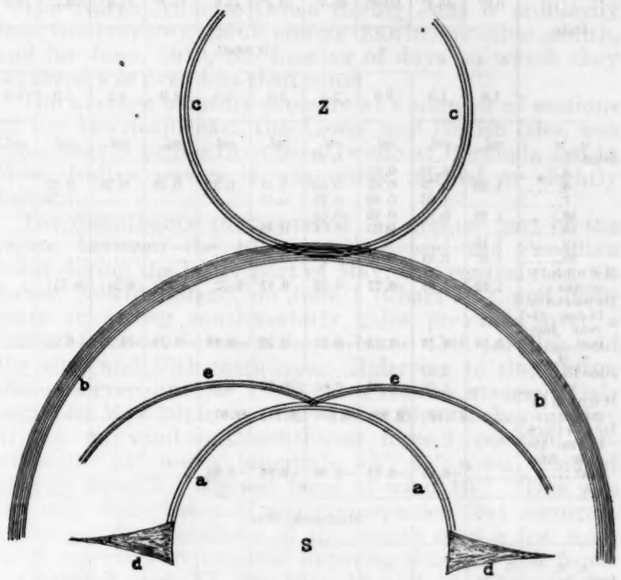

FIG. 2.—Solar halo, Juneau, Alaska, June 9, 1919, 5:30 p. m. *aa*, arc of halo of 22°, red on inside; *bb*, arc of halo of 46°, red on inside; *cc*, circumzenithal arc, red outside; *dd*, brilliant parhelia; *ee*, upper tangent arcs.

plainly visible. The parhelia were unusually prominent and brilliant. As no facilities were at hand for making measurements, the size and angles of the arcs *f* in figure 1 and *e* in figure 2 are only approximate. The arc *d* in figure 1 was measured by Charles E. Davidson, Surveyor General of Alaska, and found to be nearly 46° in radius.

The phenomenon elicited much curiosity and comment on the part of the people of this vicinity. Only a few persons had ever seen a similar display, and many old residents stated that they had never seen the like either in Alaska or the States.

SOLAR AND SKY RADIATION MEASUREMENTS DURING JUNE, 1919.

By HERBERT H. KIMBALL, Professor of Meteorology, in charge.

[Dated: Solar Radiation Investigations Section, Washington, July 30, 1919.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1919, **47**:4.

The monthly means and departures from normal in Table 1 show that the radiation measurements averaged below the June normal at all stations. The haze in the lower layers of the atmosphere, referred to in May, was not unusual after the first week in June.

Table 3 shows deficiencies of 3, 5, and 8 per cent in the total radiation for the month at Washington, Madison, and Lincoln, respectively, as compared with the normal amounts for June.

The skylight polarization measurements made at Washington on four days give a mean of 38 per cent, with a maximum of 43 per cent on the 19th. At Madison, measurements made on six days give a mean of 47 per cent, with a maximum of 57 per cent on the 28th. These are unusually low values for June.

TABLE 1.—*Solar radiation intensities during June, 1919.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 2				0.49						
3		0.72	0.61							
4	1.00	0.78	0.61	0.50	0.41	0.32	0.28	0.26	0.23	
7		1.05	0.89	0.76	0.65					
13	1.20	0.91	0.79	0.64						
18			0.65	0.54	0.46					
19	1.19									
20	1.07	0.91	0.76	0.66	0.57					
Monthly means	1.12	0.87	0.72	0.58	0.52	(0.32)	(0.28)	(0.26)	(0.23)	
Departure from 11-year normal	−0.14	−0.19	−0.18	−0.21	−0.23	−0.40	−0.36	−0.30	−0.22	
P. M.										
June 13		0.97								
19		1.06	0.95	0.85	0.75	0.67				
Monthly means		(1.02)	(0.95)	(0.85)	(0.75)	(0.67)				
Departure from 11-year normal		−0.05	−0.04	−0.06	−0.06	−0.06				

Madison, Wis.

A. M.										
June 9	1.21									
13	1.22	1.11	0.95	0.81	0.72					
19	1.18	1.01	0.87							
20			0.83							
26	1.18	0.92	0.77	0.65						
28	1.41	1.21	1.11	1.01	0.88	0.84	0.77	0.70	0.64	
30	1.09									
Monthly means	1.22	1.06	0.91	0.82	(0.80)	(0.84)	(0.77)	(0.70)	(0.64)	
Departure from 9-year normal	−0.08	−0.14	−0.19	−0.21	−0.14	−0.08	−0.11	−0.09		
P. M.										
June 12		1.03	0.92							
19		1.18								
21		1.05								
26		1.06	0.89							
28		1.27								
Monthly means		1.12	(0.90)							
Departure from 9-year normal		−0.03	−0.12							

Lincoln, Nebr.

A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 7		0.99	0.86		0.65	0.57				
17	1.30	1.11	1.00	0.90	0.80	0.70				
19		0.77	0.65							
21			0.62	0.60						
24	1.25	1.13	0.99							
25		1.18	1.04							
Monthly means	(1.28)	1.04	0.86	(0.75)	(0.72)	(0.64)				
Departures from 4-year normal	−0.07	−0.19	−0.21	−0.26	−0.20	−0.20				
P. M.										
June 17		1.19	1.06	1.00	0.92	0.84	0.77			
23		1.13	1.01	0.91	0.80	0.72	0.66	0.61		
24		1.14	1.03	0.93	0.85	0.78	0.69			
Monthly means		1.15	1.03	0.95	0.86	0.78	0.71	(0.61)		
Departures from 4-year normal		−0.07	−0.07	−0.04	−0.05	−0.07	−0.05			

TABLE 1.—*Solar radiation intensities during June, 1919*—Continued.

Santa Fe, N. Mex.

Date.	Sun's zenith distance. 0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass. 1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 4	1.44									
6			1.18	1.09						
7				1.02	0.87					
10			1.16	1.08	0.99					
11	1.35	1.26	1.17	1.05	1.01	0.93	0.86			
13	1.36			1.03	0.94	0.86				
16	1.37				0.92		0.87	0.81		
17	1.42		1.13	1.04	0.95	0.90	0.84			
20			1.23	1.14	1.06	0.98				
23		1.34		1.12	1.09	1.00				
27	1.30	1.27								
Monthly means	1.37	1.29	1.17	1.07	0.98	0.93	0.86	(0.81)		
Departures from 7-year normal	−0.08	−0.02	−0.06	−0.07	−0.06	−0.09	−0.07	−0.10		

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.	Dates.	8 a.m.	8 p.m.
1919.	mm.	mm.	1919.	mm.	mm.	1919	mm.	mm.	1919.	mm.	mm.
June 2	12.68	17.37	June 9	12.24	13.13	June 7	10.21	15.11	June 4	5.56	5.36
3	16.79	19.89	12	16.79	16.79	17	15.65	13.13	6	6.50	7.04
4	18.59	17.37	13	16.79	17.37	19	18.59	17.37	7	6.50	7.04
7	16.20	16.20	19	16.79	17.37	21	17.37	19.23	10	6.27	4.75
13	10.59	13.13	20	16.79	16.79	23	19.23	17.37	11	7.04	7.87
18	15.65	15.65	21	15.11	16.20	24	16.20	15.11	13	7.57	6.02
19	12.24	13.13	26	17.37	17.37	25	17.96	18.59	16	7.29	7.29
20	12.68	17.96	28	8.81	7.87				17	7.87	7.57
			30	10.97	14.60				20	7.57	8.48
									23	6.50	7.29
									27	8.48	7.87

TABLE 3.—*Daily totals and departures of solar and sky radiation during June, 1919.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals. Washington.	Madison.	Lincoln.	Departures from normal. Washington.	Madison.	Lincoln.	Excess or deficiency since first of month. Washington.	Madison.	Lincoln.
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
June 1	529	468	104	34	− 15	−436	34	− 15	− 436
2	560	308	611	65	−177	67	99	− 192	− 369
3	561	432	110	66	− 55	−437	165	− 247	− 806
4	596	331	422	101	−158	−128	266	− 405	− 934
5	536	352	454	41	−139	− 99	307	− 544	−1033
6	337	292	564	−160	−202	8	147	− 746	−1025
7	600	437	633	101	− 59	74	248	− 805	− 951
8	532	494	558	31	− 5	− 4	279	− 810	− 955
9	245	597	534	−259	95	− 31	20	− 715	− 986
10	368	519	498	−138	14	− 70	− 118	− 701	−1056
11	456	406	405	− 52	−102	−165	− 170	− 803	−1221
12	341	610	487	−169	99	− 86	− 339	− 704	−1307
13	650	638	578	137	124	2	− 202	− 580	−1305
14	524	466	517	9	− 51	− 62	− 193	− 631	−1367
15	474	518	481	− 43	− 2	−101	− 236	− 633	−1468
16	572	481	688	54	− 42	104	− 182	− 675	−1364
17	563	507	746	43	− 18	159	− 139	− 693	−1205
18	522	604	519	1	76	− 70	− 138	− 617	−1275
19	637	641	669	115	111	78	− 23	− 506	−1197
20	620	539	449	97	6	−144	74	− 500	−1341
Decade departure							192	201	− 285
June 21	431	654	581	− 93	119	− 14	− 19	− 381	−1355
22	765	468	704	240	− 70	107	221	− 451	−1248
23	560	316	725	34	−224	126	255	− 675	−1122
24	429	280	715	− 98	−263	114	157	− 938	−1008
25	182	395	700	−346	−150	97	− 189	−1088	− 911
26	235	632	450	−292	87	−152	− 481	−1001	−1063
27	104	296	489	−362	−249	−112	− 843	−1250	−1175
28	585	749	334	61	205	−265	− 782	−1045	−1440
29	725	729	582	202	185	− 15	− 580	− 860	−1455
30	619	620	693	98	77	98	− 482	− 783	−1357
Decade departure							− 556	− 283	− 16
Excess or deficiency since first year (Gr.-cal)							−2842	−4866	−3945
Excess or deficiency since first year (Per cent)							− 4.4	− 7.6	− 5.5

WEATHER OF THE MONTH.

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS.

GENERAL CONDITIONS.

By A. J. HENRY.

From the fragmentary information at hand it appears that atmospheric pressure over both oceans increased over that of the preceding month and that HIGHS were established in their usual positions at the season indicated by previous studies. This fact may be interpreted as indicating that the weather in general conformed closely to the seasonal average in the various parts of the Northern Hemisphere.

NORTH AMERICA.

By A. J. HENRY.

Judging by conditions as observed in the United States and Canada the primary circulation of the atmosphere was rather inactive and without distinctive characteristics. The secondary circulation was also weak, there being a decided absence of the development of severe local storms, tornadoes, and intense thunderstorms. Intense drought prevailed west of the Rockies, while rather abundant rains were the rule east of the Plains region. The temperature in the early days of the month was rather low west of the 90th meridian, but recovered and passed to the other extreme by the middle of the month. In the mountain and plateau region the dryness was coupled with high day temperatures, especially in the desert regions of the Southwest. High temperatures prevailed in the Lake region also at various times during the month.

NORTH PACIFIC OCEAN.

By F. G. TINGLEY.

From the ships' reports at hand it appears that no unusual weather conditions prevailed on the North Pacific Ocean during June. Pressure was almost continuously above normal in the Aleutian region, in marked contrast to the low pressure which prevailed there in May, and was much below normal in the vicinity of Midway Island, also in contrast to conditions during the preceding month. Elsewhere nearly normal conditions appear to have prevailed.

NORTH ATLANTIC OCEAN.

By F. A. YOUNG.

The North Atlantic Ocean during June is ordinarily freer from severe cyclonic storms than in any other month, and for June, 1919, the number of days on which they occurred was even less than usual.

The average monthly pressure at a number of stations on the American coast, the Azores, and British Isles, was considerably higher than usual, while at Bermuda and in West Indian waters it was either normal or slightly below.

The disturbance that covered the greater part of the region between the 40th meridian and the Canadian coast during the latter part of May, was central near St. Johns, Newfoundland, on June 1 (Chart IX), and moderate to strong southwesterly gales prevailed over a limited territory between the 40th and 45th parallels and the 40th and 50th meridians. Referring to this storm, the observer on the U. S. S. *Pretonia* states: "Gale began on May 30; lowest barometer 29.13 inches on May 31, 4 p. m.; wind south-southwest, force 9; position, latitude 39° 54′ north, longitude 46° 55′ west. End of gale on June 2. Highest force of wind 10." This was the only disturbance of any consequence that occurred, as during the remainder of the month only a few scattered reports were received denoting winds of gale force.

Charts X and XI, for June 14 and 15, respectively, show the general atmospheric conditions at Greenwich mean noon, shortly before the beginning and after the end of the trans-Atlantic flight made by Capt. Alcock, who left St. Johns, Newfoundland, near local noon on the 14th, arriving at Clifden, Ireland, on the morning of the 15th. (See pp. —— above.)

In the 5° square that includes Halifax, Nova Scotia, fog was observed on 17 days, or 57 per cent, while for that locality the normal percentage is about 30. Reports received from vessels in different 5° squares along the northern steamer lanes, indicate that fog occurred from 1 to 5 days during the month, while off the northern coast of Scotland it was encountered on 7 days, which is somewhat above the normal.

NOTES ON WEATHER IN OTHER PARTS OF THE WORLD.

Canada.—June 26, 1919. A tornado struck the outskirts of the small town of Empress (near Medicine Hat, Alberta) to-day, killing one and injuring several people and demolishing a number of buildings. Tornadoes are of exceptional occurrence in this region.—*N. Y. Ev. Post, June 26, 1919.*

British Isles.—Until about the 18th the type of pressure over the major part of the United Kingdom was anticyclonic, and the weather was therefore mainly fair and very dry. * * *

Between the 19th and 20th the development of a shallow depression over southern England was attended by copious and very welcome falls of rain in the Home counties; and for the remainder of the month when the prevailing winds were from between north and west the weather was cool, cloudy, and rather changeable, though mostly dry.

The general rainfall expressed as a percentage of the average was: England and Wales, 62; Scotland, 139; Ireland, 109; British Isles, 96.

In London (Camden Square) the partial drought, which had lasted for seven weeks [absolute drought, May 10–June 3 [1]] broke up on the 19th and thereafter the weather was cool and showery.—*Symons's Met'l Magazine, London, July 1919, p. 69.*

France.—Paris, June 24, 1919. The drought which has been affecting Paris and virtually all France for several weeks seems to have been broken. Rain began falling here this morning.—*Washington Post, June 25, 1919.*

Rumania.—Cold with excessive rains over a fairly wide area have been unfavorable for the corn crop and for wheat harvest.[2]

India.—The monsoon is now being experienced in India. Fairly good rains have fallen over a wide area and these have facilitated preparations for the autumn crop of native food grains.[3]

Argentina—Chile.—The Trans-Andine Railway has been blocked for some time by snowslides.[3]

Australia.—Frequent rains in the wheat regions have put the soil in excellent condition for sowing.[3]

[1] *Nature* (London), June 26, 1919, p. 329.
[2] *N. Y. Ev. Post*, June 18, 1919.
[3] Idem., June 19, 1919.

DETAILS OF THE WEATHER IN THE UNITED STATES, JUNE, 1919.

CYCLONES AND ANTICYCLONES.

By A. J. HENRY.

The usual method of classifying cyclones and anticyclones according to place of origin or first appearance on the daily weather map has little significance when applied to the current month. Practically all of the cyclones of the month first appeared in the Canadian northwest as weak disturbances or more generally as a trough of low pressure that stretched from the Gulf of California to the Canadian border. This trough was more or less a permanent feature of the month, and explains in part the unusual dryness and the high temperatures experienced in the region west of the Rockies. Each individual disturbance that advanced from the west seemed to merge with the existing trough and to completely lose its identity therein. Possibly this sequence of events was a result of the movement of anticyclones along the northern border of the United States, and to the fact that on reaching the Lake region and the Saint Lawrence Valley there was a tendency for them to increase somewhat in intensity and to move less rapidly. In any event it seems reasonable to couple the failure of the trough of low pressure west of the Rockies to break up with the persistency of high pressure in northeastern districts of the United States and Canada.

THE WEATHER ELEMENTS.

By P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, August 1, 1919.]

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds for June, 1919, are graphically shown on Chart VII, while the means at the several stations, with the departures from the normal, are shown in Tables I and III.

The month opened with high pressure in the far Northwest which during the following few days advanced into the Mountain and Great Plains regions and thence to the Great Lakes and lower St. Lawrence Valley. Another high pressure area began to develop over the eastern Canadian Provinces about the 7th and during the following few days dominated the North Atlantic coast, the pressure becoming unusually high in the far Northeast about the end of the first decade. Before pressure in these districts had returned to normal, another HIGH had moved eastward over the Great Lakes, and, merging with that just mentioned, caused an unusual persistence of pressure above normal over much of the eastern part of the country. During the latter half of the month pressure remained near the normal until toward the close when another HIGH moved southward to the Great Lakes and thence eastward to the middle Atlantic coast where it persisted at the end.

The month was marked by an unusual absence of well-defined low-pressure areas having a distinctive progressive movement, although pressure was moderately low in central and southern districts during much of the first decade, and over the Lake region near the middle of the last decade.

The average pressure for the month was above the normal in all portions of the country, except locally in the central Plateau region, the far Southwest and over the Florida Peninsula, where it was slightly below. In the region of the Great Lakes and to the eastward and southeastward the departures above the average were large, considering the period of the year.

The distribution of atmospheric pressure was not favorable for the development of high winds over any considerable areas, and such storms as were reported were distinctly local and were in the main associated with thunderstorms. Only in a few instances were velocities as great as 50 miles an hour recorded and these were at widely separated points. The persistence of high pressure in the Lake region and Northeast favored the usual trend of anticyclonic winds, and their directions were mainly from easterly courses over the east Gulf and South Atlantic States, and from southeast to south in the West Gulf, Central Valleys and Plains region. West of the Rockies the usual diversity of direction prevailed, although near the coast they were mainly from the northwest.

TEMPERATURE.

June opened with cool weather in the far West and by the morning of the 3d freezing temperature had occurred over much of the Middle Plateau and Rocky Mountain districts, and into the Central Plains States. The temperature at points along the eastern slopes of the Rockies during this period reached new low levels for the month of June and serious damage from frost and freezing resulted over extensive areas. During this cold period in the West more moderate conditions were the rule to the eastward, and by the middle of the first decade temperature in practically all districts had risen to normal, or above, and moderately warm weather continued during the remainder of the decade, except for a sharp cool spell during the last few days in the Northern Plateau, where heavy frosts were reported on the morning of the 7th.

Throughout the second decade temperatures were generally above the normal in the districts from the Rocky Mountains eastward, and frequently below in the States to the westward, particularly during the first few days, heavy frosts being reported from points in the Northern Plateau about the 12th. By the end of the decade, however, temperatures had risen above the normal over the greater part of the country.

During the early part of the third decade warm weather continued, the day temperatures frequently rising above 100° at points in the Northwest, and near the middle of the decade there was a decided rise in temperature over the northeastern districts. During the latter part of the month a cool area of considerable magnitude overspread the Lake region and, extending southward and eastward, brought sharp falls in temperature over the greater part of the eastern third of the country, the cool weather continuing till the end of the month over the Atlantic coast districts, light frosts being reported at exposed points from the lowlands of New Jersey to New England, on the mornings of the 29th and 30th. In most other districts the weather continued warm at the end of the month.

Maximum temperatures of 100° or higher occurred during some period of the month in practically all States of the Union, the extreme, 121°, being reported from the desert region of California, while values of 110° or slightly

higher were observed locally in the middle Plateau region. At a few points in the lower Lake region and Middle Atlantic States, the maximum temperatures on the 4th were the highest of record for June.

Minimum temperatures were below 32° at points in all the Mountain States of the West, and over much of the Great Plains from Nebraska northward, and locally in the Lake region and Northeastern States. The lowest reported, 10°, was observed in the high mountains of Utah, and readings nearly as low were reported from points as far south as central New Mexico.

For the month, as a whole, the temperature averaged higher than normal in most central and northern districts, the departures being exceptionally large for a summer month in the northern Rocky Mountain district and in the region of the Great Lakes, Ohio Valley, and adjoining sections. The month was markedly warm throughout in the Lake region, some stations reporting temperature above normal each day in the month, except the 27th and 28th, and over Michigan and portions of adjoining States the month was the warmest June in 50 years or more. While temperatures remained almost continuously above normal in the Lake region, they were as persistently below in portions of the Southwest, where at points in Texas and New Mexico the temperatures did not rise above the normal during the entire month and in some sections it appears to have been the coolest June since observations began.

PRECIPITATION.

Showery weather obtained in most central districts at the beginning of the month, but from the Ohio Valley and Middle Atlantic States northeastward, and west of the Rockies the weather was clear. During the next few days rain became general in the Gulf States, the Mississippi and lower Missouri Valleys, and the western Lake region. About the middle of the first decade showers, mostly moderate to light, were received in nearly all central and northern districts, from the Great Plains eastward, and also in portions of the South Atlantic States, and for several days following there were local rains east of the Mississippi River, except along the immediate Gulf coast and in some South Atlantic districts, and at the same time showers occurred in the central and southern Rocky Mountain sections and in most of the Great Plains. The falls were heavy in the South Atlantic States and in portions of the Lake region, the Ohio Valley, and Central Plains States. At the close of the decade there were showers in New England, the Western Gulf States and from the central and southern Plains northeastward to the Great Lakes, and in portions of Tennessee, and the adjoining States, and along the North Pacific coast.

The beginning of the second decade was marked by showers from eastern Texas, Louisiana, and western Mississippi northward to the Canadian border, and local rains were received in the Southeast and far Northwest. During the following few days unsettled, showery weather prevailed in the north-central, central, and southern districts, the rainfall being heavy in parts of North Dakota and in extreme southern Florida. About the middle of the month showers were quite general in the West Gulf States, the Lake region, and from the upper Ohio Valley and middle Atlantic coast States northeastward; the rainfall being heavy in southeastern Texas. During the latter part of the decade showers occurred in the central and southern Rocky Mountain districts and in nearly all sections between the Rockies and the Mississippi River, and also in the Lake region, Tennessee, and northern portions of the East Gulf States and in most of Florida.

Early during the third decade showery weather obtained from the Ohio Valley southward, in the West Gulf States, the central and upper Mississippi Valley, and the northern Plains. Toward the middle of the decade general rains prevailed in the western upper Lake region, the Mississippi Valley, the southern Plains, and in most localities from the Ohio Valley and West Virginia southward, the rainfall being heavy in the lower Ohio Valley and portions of Tennessee. This rainy condition extended during the next few days into the East and South with heavy falls in many portions, particularly along the middle Atlantic coast where locally 5 inches or more occurred in 24 hours. The month closed with the weather clear in all districts except over portions of the Gulf States.

For the month as a whole precipitation was copious and generally above normal from Texas and Louisiana northward to South Dakota and Minnesota, and generally over the East Gulf and South Atlantic States, the monthly falls over these areas ranging largely from 4 to 8 inches, with small sections having as high as 10 to 12 inches. In other districts east of the Rocky Mountains the precipitation was generally less than normal although its distribution through the month was such that no serious drought was reported in any district, and as a rule the amounts received were abundant for all needs. To westward of the Rocky Mountains there was practically everywhere a deficiency in the rainfall and particularly so in the more northern districts. In portions of Montana the precipitation was the least of record for June, and one of the worst droughts in the history of the State was being experienced at the end of the month. In other portions of the far West, particularly in the Great Basin region and California, the month was unusually dry, and much injury had resulted, not only in the unirrigated regions but even where irrigation is practiced, due to the low levels of the streams, caused by the general lack of the usual supply of snow in the high mountains.

RELATIVE HUMIDITY.

From the Rocky Mountains eastward to the Mississippi River the relative humidity was practically everywhere higher than the normal, the excess being unusually great in portions of Texas and eastern New Mexico and the adjoining districts to the northward. East of the Mississippi River there were no large departures either above or below the normal. West of the Rocky Mountains the general absence of moisture is reflected in the low humidity readings which were in special cases from 15 to 25 per cent less than the average. Over extensive areas between the Rocky and Sierra Mountains, the average relative humidity at noon, local time, for the entire month was less than 20 per cent and at some points scarcely more than 10 per cent. The sections having the highest humidity at noon included the Upper Lake region and the several coasts, although points in the middle Plains had relative humidity nearly as great.

SEVERE STORMS.

A severe tornado visited Fergus Falls, Minn., and vicinity June 22, 1919, during which 57 persons were reported killed, 88 injured and three and a half million dollars' worth of property destroyed. A full account of the storm will be found in another portion

of this REVIEW (see pp. 392–393). Thunderstorms were numerous but apparently not notably severe, except in a few instances. At Evansville, Ind., a severe wind and electrical storm occurred on the evening of the 2d causing great damage, the wind attaining the unusually high velocity of 150 miles per hour for a brief period. At Broken Arrow, Okla., a severe wind, rain, and hail storm occurred on the 6th causing great damage in the surrounding country (see pp. 391–392 above). At Cairo, Ill., a severe wind and hail storm on the afternoon of the 8th caused great damage to crops. Near Ionia, Iowa, about the 16th reports indicate the occurrence of a near-tornado with considerable damage over a narrow but considerably extended area; and reports from Oakland, Ill., state that a storm with tornado characteristics swept over that place on the evening of the 24th, doing considerable property damage.

Average accumulated departures for June, 1919.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	° F.	° F.	° F.	In.	In.	In.	0–10		P. ct.	
New England	64.6	+1.0	+14.6	2.00	−1.20	+1.50	5.0	−0.3	78	− 1
Middle Atlantic	71.3	+1.0	+14.2	3.09	−0.50	−0.40	5.1	0.0	75	− 2
South Atlantic	75.5	−0.6	+ 5.1	5.95	+1.00	−2.00	5.9	+0.9	78	+ 1
Florida Peninsula	79.7	−1.1	− 2.8	8.74	+1.90	+8.80	7.3	+2.2	78	0
East Gulf	78.3	+0.2	− 1.5	4.06	−0.50	+5.10	6.1	+1.1	77	+ 2
West Gulf	77.0	−2.0	− 5.0	6.23	+2.50	+2.30	5.9	+1.6	79	+ 5
Ohio Valley and Tennessee	76.1	+3.1	+ 8.2	4.00	−0.20	−1.50	5.2	+0.2	72	+ 1
Lower Lakes	72.6	+5.6	+16.8	2.61	−0.90	−0.50	3.7	−1.2	69	− 2
Upper Lakes	68.4	+5.9	+23.6	2.51	−0.80	−1.50	4.1	−1.0	75	+ 2
North Dakota	68.4	+4.7	+22.7	2.34	−1.30	−0.70	3.9	−1.2	69	0
Upper Mississippi Valley	74.0	+3.1	+16.0	4.78	+0.40	−0.40	5.6	+0.6	76	+ 6
Missouri Valley	72.5	+1.6	+16.6	4.29	0.00	−1.00	5.9	+0.9	76	+ 9
Northern slope	65.8	+3.7	+17.8	1.33	−0.90	−3.00	3.5	−1.3	50	−10
Middle slope	71.2	−0.7	+ 3.9	2.85	−0.30	−2.10	4.8	+0.8	67	+ 6
Southern slope	73.1	−4.1	−10.4	2.84	+0.20	+3.50	4.8	+1.0	69	+11
Southern Plateau	74.2	−0.4	− 6.4	0.35	0.00	+0.40	1.7	−0.3	35	+ 5
Middle Plateau	67.9	+2.2	+ 7.7	0.03	−0.40	−2.20	1.3	−2.0	28	−10
Northern Plateau	64.9	0.0	+ 9.4	0.03	−1.10	−2.50	3.4	−1.1	37	−15
North Pacific	56.8	−1.5	+ 3.4	0.87	−1.10	+1.40	4.9	−1.1	72	− 4
Middle Pacific	61.6	−1.0	− 0.7	0.02	−0.40	−2.00	1.5	−1.6	59	− 5
South Pacific	68.1	+1.4	+ 4.4	0.00	−0.10	−3.80	1.2	−2.0	60	− 6

Winds of 50 mis./hr. (22.4 m./sec.) or over, during June, 1919.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
Bismarck, N. Dak.	12	63	sw.	Mount Tamalpais, Calif.	26	66	nw.
Cairo, Ill.	8	59	sw.	Do.	27	54	nw.
Dayton, Ohio.	16	50	ne.	Do.	29	56	nw.
Drexel, Nebr.	19	56	e.	Norfolk, Va.	7	67	nw.
Do.	25	50	nw.	North Head, Wash.	21	52	se.
El Paso, Tex.	13	53	ne.	Pierre, S. Dak.	26	54	ne.
Evansville, Ind.	2	67	s.	Point Reyes Light, Calif.	8	67	nw.
Kansas City, Mo.	26	50	n.	Do.	9	66	nw.
Modena, Utah.	10	51	sw.	Do.	10	68	nw.
Mount Tamalpais, Calif.	8	62	nw.	Do.	11	51	nw.
Do.	9	84	nw.	Do.	16	55	nw.
Do.	10	80	nw.	Do.	17	60	nw.
Do.	13	56	nw.	Do.	18	61	nw.
Do.	14	72	nw.	Do.	19	58	nw.
Do.	15	78	nw.	Do.	25	50	nw.
Do.	16	72	nw.	Do.	27	54	nw.
Do.	17	68	nw.	Do.	28	58	nw.
Do.	18	66	nw.	Do.	29	50	nw.
Do.	19	88	nw.	St. Joseph, Mo.	26	54	nw.
Do.	20	54	nw.	St. Louis, Mo.	16	69	sw.
Do.	22	52	nw.	Williston, N. Dak.	29	60	w.
Do.	25	54	nw.				

SPECIAL FORECASTS AND WARNINGS—WEATHER AND CROPS.

WEATHER WARNINGS.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Weather Bureau, Washington, July 17, 1919.]

Cyclonic activity was quite feeble during the month, and but a single storm warning was necessary. During the last week a trough of moderately low pressure drifted slowly across the country, and on the morning of the 28th, it extended from the North Carolina coast northeastward over the ocean to Newfoundland. High pressure and low temperature followed from the northwest, with the crest of the wave over Ontario on the date mentioned. Northeast storm warnings were therefore ordered along the Atlantic coast from Norfolk, Va., to Nantucket, Mass., for strong northeast winds on the immediate coast and gales at sea. The winds occurred as forecast within the ensuing twenty-four hours.

Small-craft warnings were also ordered on June 10 for western Lake Superior, and on June 25 for Lake Erie from Cleveland to Buffalo.

WARNINGS FROM OTHER DISTRICTS.

Chicago, Ill., Forecast District.—No frost warnings were issued for any portion of the district after the 3d. On the 1st frost, or freezing temperature, was predicted for Wyoming and the warning was fully verified. Frost warnings were issued for the lowlands of Minnesota and the cranberry bogs of Wisconsin on the 2d, and for northwestern Nebraska and southeastern Wyoming on the following day; however, cloudiness prevented frost formation.—*Charles L. Mitchell.*

New Orleans, La., Forecast District.—Northeast storm warnings were ordered on the 14th at 9 p. m. for the Texas coast from Velasco to Port Arthur, and small craft warnings on the 16th for the same territory. Subsequent conditions justified the display.

No general storm occurred without warning.

An area of high pressure over the eastern Rocky Mountain region and the Plateau States, with record low temperatures on the morning of the 2d, indicated frost for Oklahoma and northwestern Texas, and warnings were issued for that area. Temperatures on the morning of June 3 were 44° to 50° in Oklahoma and northwestern Texas.—*I. M. Cline.*

Denver, Colo., forecast district.—The anticyclone that appeared in Oregon on May 31 resulted in record-breaking low temperatures in Colorado and heavy frost or freezing temperature in parts of New Mexico, Arizona, and Utah on June 1. Several stations in Colorado reported the lowest temperatures of record for June. These conditions were fully covered by the warnings issued by the district forecaster on May 31. The anticyclone spread eastward over the northern portions of the Plateau and Rocky Mountain regions, necessitating warnings on the morning of June 1 for continued cold weather, with frosts, in Colorado, northern New Mexico, northern Arizona, and Utah. Freezing temperatures again occurred in Colorado and northern New Mexico and frost temperatures in northern Arizona and Utah. The damage from frost on the 1st and 2d was variable; in a few localities the freeze was destructive to some important crops; in general, however, frosted crops revived, although their growth was retarded. Frost warnings were repeated for Colorado and high districts in Utah on June 3, as the crest of the anticyclone was still in the Rocky Mountain region. Frost temperatures occurred in the areas indicated. No other frost warnings were issued, except on one date for high districts in Utah.

Moderately low pressure and unusually warm and dry weather prevailed generally during the remainder of the month, except in parts of New Mexico, where summer rains occurred earlier than usual. Drought resulted in portions of Colorado and Utah, followed by a shortage of water for irrigation.

Fire-weather warnings were issued for large areas in the district on the 10th, and during the closing days of the month, when the prevailing hot and dry weather had rendered the forested areas unusually susceptible to the spread of fires. The warnings were fully justified, strong winds being reported in various localities in the area embraced by the warnings.—*Frederick W. Brist.*

San Francisco, Calif., forecast district.—No well-developed HIGHS or LOWS passed across the district during the month of June. Pressure distribution followed the usual summer type and consisted of relatively high barometric readings along the north Pacific coast and relatively low readings over the Plateau States. A good part of the time a large high pressure area over the Atlantic States blocked the eastward passage of the "heat" LOWS forming over the Plateau States, and in consequence temperatures in this district averaged nearly normal, except in southeastern Idaho and southern Nevada, where it was slightly warmer than usual. Local rains fell on several days in western Oregon, western Washington, and extreme northwestern California. None of consequence fell elsewhere.

Frost warnings were issued on the 10th, 11th, 14th, and 17th for portions of the North Pacific States and they were generally verified. Fire-weather warnings were issued for northern California on the 3d and 23d, which also were verified. During the last decade the forests dried very rapidly and many of them had reached the state where fires could easily occur, and, had there been even moderately high winds, would have spread to an alarming extent. Foreseeing on the 26th that lower temperatures would occur in Idaho and that showers were liable to fall in the mountains, a warning to this effect was sent to the forest people in Idaho and northern Nevada. Within the next 24 to 36 hours much cooler weather prevailed, which undoubtedly greatly lessened the fire hazard in the localities where the warnings were distributed.—*E. A. Beals.*

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RIVERS AND FLOODS, JUNE, 1919.

By ALFRED J. HENRY, Meteorologist in Charge.

The month as a rule was devoid of severe floods, although heavy rains fell locally in various parts of the country, especially in the last decade. At this time moderate floods occurred in the rivers of the Carolinas. Also in the rivers of Texas, the flood on the lower Trinity from June 28 to July 7, was in the nature of a severe flood.

In the great interior drainage light local floods occurred on various rivers and on sundry dates. In general, however, the streams were at a moderately low state for June, and did not quickly respond to heavy rains.

In the region west of the Rockies the dryness was quite noticeable and apparently resulted in a reduced flow both in the Colorado and Columbia Rivers.

The usual details follow:

Estimated loss due to floods, June, 1919.

District.	Tangible property.	Crops.		Live stock.	Suspension of business.	Value of warnings
		Present.	Prospective.			
Columbia, S. C.				$100	$950	$76,000
Houston, Tex.		$500	$750,000	10,000		20,000
Mobile, Ala.			25,000			

TABLE I.—*Flood stages in the Atlantic drainage during the month of June, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Staunton:	*Feet.*			*Feet.*	
Randolph, Va.	21	27	28	24.2	28
Roanoke:					
Weldon, N. C.	30	28	(*)	34.5	29
Neuse:					
Neuse, N. C.	14	8	9	14.8	9
Smithfield, N. C.	14	10	10	14.1	10
Santee:					
Ferguson, S. C.	12	28	(*)	12.9	30
Wateree:					
Camden, S. C.	24	28	28	25.6	28

* Continued into July.

TABLE II.—*Flood stages in the Mississippi drainage during the month of June, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Kanawha:	*Feet.*			*Feet.*	
Glenville, W. Va.	22	26	26	23.0	26
Mississippi:					
Hannibal, Mo.	13	7	10	13.2	9
Arkansas City, Ark.	42	(**)	12	44.1	† 29–30
Minnesota:					
Mankota, Minn.	18	21	22	18.9	21
Des Moines:					
Ottumwa, Iowa	10	4	9	13.1	8
		12	12	10.2	12
Illinois:					
Henry, Ill.	7	(**)	10	13.3	† 10–11
Havana, Ill.	14	5	8	14.1	6–7
Beardstown, Ill.	12	(**)	20	15.6	8
		29	(*)	12.2	30
Pearl, Ill.	12	4	14	13.8	9
Grand:					
Chillicothe, Mo.	18	4	13	20.8	5
Brunswick, Mo.	10	7	15	15.5	8
Meramec:					
Pacific, Mo.	11	5	6	14.5	6
Bourbeuse:					
Union, Mo.	10	5	5	11.1	5
Blue:					
Blue Rapids, Kans.	20	11	11	20.2	11
Smoky Hill:					
Lindsborg, Kans.	19	11	11	19.3	11
Solomon:					
Beloit, Kans.	18	10	13	23.7	11
Black:					
Black Rock, Ark.	14	4	15	16.5	8
		24	27	17.4	24
Cache:					
Jelks, Ark.	9	22	25	9.1	24

** Continued from May. * Continued into July. † May.

TABLE IV.—*Flood stages in the West Gulf drainage during the month of June, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Trinity:	*Feet.*			*Feet.*	
Liberty, Tex.	25	28	(*)	26.1	30
Colorado:					
Columbus, Tex.	28	16	18	33.6	17
		27	28	30.4	27
Guadalupe:					
Gonzales, Tex.	22	18	19	24.3	18
		28	29	26.3	28
Victoria, Tex.	16	13	14	16.9	13
		17	23	22.6	21–22
		28	(*)	21.9	30
Rio Grande:					
San Marcial, N. Mex.	14	3	3	14.0	3

* Continued into July.

TABLE V.—*Flood stages in the Pacific drainage during the month of June, 1919.*

River and station.	Flood stage.	Above flood stages—dates.		Crest.	
		From—	To—	Stage.	Date.
Columbia:	*Feet.*			*Feet.*	
Marcus, Wash.	24	(**)	(*)	27.5	1–2
Vancouver, Wash.	15	(**)	13	19.3	1–2
Kootenai:					
Bonners Ferry, Idaho	26	(**)	2	28.7	† 30
Willamette:					
Portland, Oreg.	15	(**)	13	18.6	1–2

** Continued from May. * Continued into July. † May.

MEAN LAKE LEVELS DURING JUNE, 1919.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., July 7, 1919.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during June, 1919:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	602.45	581.50	573.77	247.95
Above or below—				
Mean stage of May, 1919	+0.20	+0.12	+0.08	+0.68
Mean stage of June, 1918	+0.34	−0.45	+1.23	+0.94
Average stage for June, last 10 years	+0.24	+0.68	+0.92	+1.06
Highest recorded June stage	−0.98	−2.10	−0.75	−0.68
Lowest recorded June stage	+1.21	+1.60	+2.20	+3.06
Average relation of the June level to:				
May level		+0.3	+0.2	+0.2
July level		−0.1	+0.1	+0.1

* Lake St. Clair's level: In June, 576.45 feet.

EFFECT OF WEATHER ON CROPS, JUNE, 1919.

By J. B. KINCER, Meteorologist.

Farm work.—The continuation of frequent rains from Missouri and eastern Kansas northward were unfavorable for farm work during much of the month and planting and cultivation were delayed in that area, while like conditions hindered outdoor operations in the Southeast and in the west Gulf region. In most other sections of the country the month was favorable for farm work, particularly in the far western States where there was little or no interruption by rain.

Winter grains.—The month was generally favorable for the development of winter wheat, except that it was too dry from the central Rocky Mountain districts westward and northwestward, and the frequent rains were rather unfavorable in some interior sections, by causing too rank growth with considerable lodging. Rye and barley made favorable advance, except where the soil was too dry, principally in the far western and northwestern States. The harvest of winter grains progressed during the month northward to Pennsylvania, Illinois, and southeastern Nebraska under mostly favorable weather conditions except for some interruption by rain in the South.

Spring crops.—The weather was generally favorable for satisfactory advancement of spring grain in most sections east of Montana and the Rocky Mountains, except that rain was insufficient for best results in portions of the western Lake region and temperatures were somewhat too high about the middle of the month for best development of oats from the lower Ohio Valley northward. It was much too dry for spring grains from western North Dakota and the central Rocky Mountain area westward and in the Canadian northwest, but wherever these crops were under irrigation good advance was made.

The cool, cloudy, and rainy weather the first of the month was unfavorable for corn in many interior districts, especially in the Great Plains area, and planting and cultivation were delayed. The last half of the month, however, was much more favorable and corn made satisfactory advance.

Much of the month was fairly favorable for cotton in the eastern protion of the belt, but it was too cool and rainy as a rule for this crop, particularly in the western cotton growing districts. The weather favored the boll weevil in the southern half of the cotton belt. Low temperatures persisted and rainfall was especially heavy in the Southeast and in the west Gulf region where many localities received from 8 to 12 inches, or more, during the month; there were many complaints of grassy fields and delay in chopping out. Truck crops, potatoes, and meadows made favorable advance in most districts, except where the soil was too dry and the crops not under irrigation, in the far western States.

CLIMATOLOGICAL TABLES.*

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, June, 1919.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	78.5	+0.4	Ashville	100	15	2 stations	56	6	4.17	+0.07	St. Bernard	11.42	Wetumpka	1.29
Arizona	77.1	+0.9	Mohawk	120	26	Snowflake	20	2	0.22	−0.09	Fort Huachuca	4.47	33 stations	0.00
Arkansas	76.9	+0.1	Pine Bluff	100	17†	Mount Ida	45	4	5.11	+1.12	Pocahontas	9.80	Princeton	2.07
California	67.9	−1.1	2 stations	121	26†	La Porte	22	11	0.01	−0.30	Crescent City	0.47	212 stations	0.00
Colorado	60.6	+0.3	2 stations	104	29	2 stations	10	2	0.87	−0.47	Burlington	5.14	6 stations	0.00
Florida	79.0	−0.9	Jasper	100	22†	Orange City	36	15	7.16	+0.69	Switzerland	15.48	Garniers (near)	0.95
Georgia	77.7	−0.1	Alapaha	101	22	Tate	53	7	5.97	+1.47	Statesboro	16.55	Griffin	1.46
Hawaii (May)	71.7	+0.2	Mahukona	95	23	Glenwood	44	2	3.41	−2.39	Eke Maui	18.50	4 stations	0.00
Idaho	61.3	+2.5	Weiser	109	22	Obsidian	15	1	0.05	−1.20	Wallace	0.71	66 stations	0.00
Illinois	75.0	+3.7	6 stations	96	13†	Sycamore	44	28	4.61	+0.81	Nashville	9.97	Sycamore	1.52
Indiana	75.3	+3.7	Crawfordsville	98	12	Howe	44	28	3.67	−0.08	Decker	9.83	Veedersburg	1.22
Iowa	71.9	+2.8	Onawa	98	23	Chariton	41	4	6.13	+1.75	Alta	12.25	Keosauqua	1.82
Kansas	72.3	−0.5	Abilene	103	25	2 stations	33	2	4.51	+0.27	Marion	8.74	Deerfield	0.32
Kentucky	76.7	+3.0	Earlington	103	17	Beattyville	51	29	3.99	−0.19	Weeksbury	8.04	Franklin	1.48
Louisiana	78.3	−1.7	Robeline	101	18	Kelley (near)	46	4	6.63	+1.65	Paradis	13.74	Dodson	1.54
Maryland-Delaware	72.1	+2.0	2 stations	98	3	Grantsville, Md	40	28	3.11	−0.93	Frederick, Md	5.47	Millsboro, Del	0.54
Michigan	70.4	+7.0	do	99	1†	2 stations	29	28	2.25	−0.75	Maple Ridge	5.33	Seney	0.18
Minnesota	67.9	+3.3	Lynd	96	18	Roseau	27	3	5.32	+1.23	Canby	10.10	Hallock	1.66
Mississippi	78.3	−0.4	Greenwood	101	17	Scott	51	4	5.01	+0.57	Enterprise	9.95	Edwards	2.08
Missouri	75.0	+1.9	Caruthersville	104	16†	Cassville	44	4	5.59	+1.11	Nevada	10.69	Gorin	1.91
Montana	64.3	+4.5	4 stations	107	26†	Bowen	16	8	0.66	−2.14	White Water	3.42	Harlowton	0.00
Nebraska	70.0	+0.9	Ainsworth	105	23	Gordon	25	3	4.94	+1.10	Imperial	13.73	Melbeta	0.71
Nevada	65.7	+1.2	Logandale	112	27	2 stations	22	1	0.00	−0.50	5 stations	T.	41 stations	0.00
New England	66.0	+1.4	2 stations	102	3†	Somerset, Vt	22	22	2.15	−1.05	Enosburg Falls, Vt.	5.12	Vernon, Vt	0.82
New Jersey	69.5	+0.3	do	99	3†	Culvers Lake	37	29	3.16	−0.60	Culvers Lake	6.45	Cape May	1.15
New Mexico	65.6	−2.8	Blackrock	103	28	Harveys Upper Ranch.	15	2	1.79	+0.63	Harveys Upper Ranch.	7.48	Farmington	0.00
New York	69.3	+4.6	Indian Lake	105	5	Gabriels	24	29	2.91	−0.64	Bolivar	6.22	Buffalo	0.54
North Carolina	73.1	−0.5	2 stations	100	21	Wenona	43	14	5.04	−0.21	Highlands	10.00	Durham	1.66
North Dakota	67.1	+4.3	4 stations	108	28†	Howard	22	2	3.32	−1.18	Cando	8.70	Dickinson	0.52
Ohio	74.2	+5.2	Milligan	100	1	2 stations	41	29	2.88	−1.05	2 stations	7.89	Sandusky	0.91
Oklahoma	74.5	−1.8	Sallisaw	100	7	Kenton	34	3	4.29	+0.70	Tulsa	9.45	Hugo	1.05
Oregon	59.4	−0.6	Valé	103	19	Lapine	12	11	0.42	−1.03	Cascadia	2.26	11 stations	0.00
Pennsylvania	71.2	+4.0	Palmerton	102	3	West Bingham	32	29	3.90	0.00	Franklin	9.17	Somerset	1.74
Porto Rico	79.4	+1.0	Canovanas	98	19	Lares	59	23	7.14	+0.22	Canovanas	18.54	Cabo Rojo	1.12
South Carolina	76.4	−1.1	Society Hill	101	21	Walhalla	46	7	5.97	+0.98	Walhalla	11.99	Columbia	2.65
South Dakota	68.7	+2.6	Camp Crook	108	29	Bellefourche	21	2	3.20	+0.50	Brookings	9.30	Greenmont	0.07
Tennessee	76.6	+2.1	3 stations	98	16†	Mountain City	49	6†	4.03	−0.27	Sewanee	9.32	Carthage	0.96
Texas	76.3	−3.6	Knickerbocker	105	12	Big Spring	34	3	5.80	+3.02	Hitchcock	21.51	Crowell	0.00
Utah	66.9	+3.1	St. John	110	25	Black's Fork	10	1	0.03	−0.62	2 stations	0.35	61 stations	0.00
Virginia	72.2	+0.7	Lincoln	99	21	Catawba Sanatorium	42	29	4.70	+0.43	Catawba Sanatorium	9.91	West Point	2.31
Washington	58.8	−1.6	3 stations	100	19	Colfax	23	8	0.63	−0.98	Quiniault	5.57	11 stations	0.00
West Virginia	73.0	+3.8	2 stations	100	1†	Marlinton	40	30	5.06	+0.51	Camden-on-Gauley	10.15	Moundsville	1.67
Wisconsin	69.4	+4.9	Osceola	96	19	6 stations	35	28	4.78	+0.87	Antigo	9.55	Kewaunee	0.43
Wyoming	63.3	+4.7	Lovell	111	29	2 stations	12	2	0.53	−1.08	Chugwater	1.84	3 stations	0.00

* For explanation of the following table and charts, see this REVIEW, Jan. 1919, pp. 52-53. † Other dates also.

TABLE 1.—*Climatological data for Weather Bureau Stations, June, 1919.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F*		°*F*	°*F*		°*F*	°*F*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
New England.							**64.6**	**+ 1.0**											**78**	**2.00**	**− 1.2**									**5.0**		
Eastport	76	67	85	30.03	30.11	+ .18	55.2	+ 0.8	84	4	64	39	1	46	36		51	48	83	1.25	− 2.0	7	5,975	s.	29	ne.	7	5	17	8	5.7	.....	.....
Greenville, Me	1,070	6	.....	28.97	30.12	.....	63.8	.....	93	3	77	31	23	51	48		.....	.....	.....	2.25	.....	12	.....	.....	.....	.....	.....	15	10	5	.....	.....	.....
Portland, Me	103	82	117	30.02	30.14	+ .19	62.9	+ 0.3	92	3	72	45	23	54	36		57	53	74	1.71	− 1.6	8	5,776	s.	25	ne.	7	12	10	8	4.7	.....	.....
Concord	288	70	79	29.83	30.14	+ .18	66.8	+ 2.4	101	4	80	39	23	54	41		.....	.....	.....	1.64	− 1.7	4	2,867	se.	18	nw.	21	17	7	6	3.8	.....	.....
Burlington	404	11	48	29.68	30.11	+ .15	66.8	+ 3.0	94	3	77	37	29	57	33		.....	.....	.....	1.64	− 1.6	9	6,883	s.	34	s.	26	10	9	11	5.5	.....	.....
Northfield	876	12	60	29.20	30.13	+ .17	64.6	+ 1.9	96	4	78	32	29	51	41		60	57	78	2.47	− 0.8	11	4,173	s.	26	n.	22	6	18	6	5.7	.....	.....
Boston	125	115	188	30.00	30.13	+ .17	67.2	+ 1.4	98	3	76	49	29	58	34		60	55	69	1.08	− 2.0	3	6,171	sw.	25	n.	7	7	14	9	5.6	.....	.....
Nantucket	12	14	90	30.12	30.13	+ .15	60.8	− 0.5	78	24	67	49	9	55	22		57	56	88	2.82	+ 0.4	8	11,316	ne.	32	sw.	27	10	12	8	5.0	.....	.....
Block Island	26	11	46	30.10	30.13	+ .16	62.2	+ 0.6	80	24	68	51	1	56	20		60	59	94	2.45	− 0.4	5	10,254	sw.	36	ne.	28	9	10	11	6.0	.....	.....
Providence	160	215	251	29.96	30.13	+ .16	66.8	− 1.5	94	4	77	46	29	57	30		60	55	70	3.23	+ 0.1	7	7,086	sw.	30	ne.	7	11	12	7	4.7	.....	.....
Hartford	159	122	140	29.96	30.13	+ .16	69.0	+ 1.9	98	4	80	46	29	58	35		61	57	71	1.54	− 1.5	5	5,255	s.	26	sw.	26	15	6	9	4.5	.....	.....
New Haven	106	117	155	30.02	30.13	+ .16	67.8	+ 0.9	93	4	77	48	23	59	32		61	57	72	2.19	− 1.0	6	5,922	sw.	26	ne.	28	13	10	7	4.3	.....	.....
Middle Atlantic States.							**71.3**	**+ 1.0**											**75**	**3.09**	**− 0.5**									**5.1**		
Albany	97	102	115	30.00	30.10	+ .13	71.1	+ 3.2	97	4	81	46	29	61	33		64	60	70	1.10	− 2.7	8	5,294	s.	26	n.	28	16	8	6	3.9	.....	.....
Binghamton	871	10	69	29.20	30.11	+ .14	70.8	+ 4.6	96	4	82	44	23	59	38		.....	.....	.....	2.49	− 1.1	9	3,383	ne.	34	e.	15	17	7	6	3.8	.....	.....
New York	314	414	454	29.80	30.12	+ .14	69.7	+ 1.2	92	4	78	52	29	62	34		62	57	71	2.23	− 1.0	6	8,604	s.	48	n.	20	10	11	9	5.3	.....	.....
Harrisburg	374	94	104	29.73	30.12	+ .13	72.6	+ 2.3	96	3	82	52	23	63	32		64	60	70	3.90	+ 0.4	11	3,855	s.	39	n.	15	6	14	10	5.8	.....	.....
Philadelphia	117	123	190	30.01	30.13	+ .15	72.0	+ 0.8	97	3	81	53	29	63	28		65	62	75	2.19	− 1.1	8	6,364	s.	33	ne.	28	11	10	9	5.0	.....	.....
Reading	325	81	98	29.78	30.12	.....	72.1	.....	97	3	82	51	30	63	31		64	60	72	2.46	− 1.2	10	4,049	se.	28	nw.	20	12	8	10	5.3	.....	.....
Scranton	805	111	119	29.28	30.13	+ .15	71.7	+ 4.5	99	3	83	46	23	60	35		64	61	74	4.46	+ 0.9	9	3,749	n.	27	e.	15	9	8	13	6.0	.....	.....
Atlantic City	52	37	48	30.07	30.13	+ .15	66.4	− 0.4	84	3	71	52	30	62	25		63	61	84	2.90	− 0.1	10	5,082	s.	36	ne.	28	13	8	9	4.7	.....	.....
Cape May	18	13	49	30.14	30.16	+ .18	67.4	− 0.3	85	3	74	50	30	61	29		64	62	84	1.15	− 1.9	7	5,456	s.	30	ne.	28	11	8	11	5.3	.....	.....
Sandy Hook	22	10	57	30.11	30.13	.....	68.0	.....	87	4	75	55	29	61	27		62	60	81	2.50	.....	7	8,648	se.	49	nw.	20	12	13	5	4.8	.....	.....
Trenton	190	159	183	29.92	30.12	.....	70.8	.....	96	3	81	50	29	61	35		62	58	70	1.39	− 2.1	6	6,582	s.	34	ne.	28	8	12	10	5.7	.....	.....
Baltimore	123	100	113	29.99	30.12	+ .13	73.4	+ 0.4	95	3	81	54	30	65	26		66	62	71	2.69	− 1.2	10	4,469	se.	30	n.	20	12	8	10	5.0	.....	.....
Washington	112	62	85	30.00	30.11	+ .11	73.9	+ 1.2	93	3	83	50	30	65	30		66	62	71	3.44	− 0.7	10	3,682	s.	24	n.	20	11	9	10	5.4	.....	.....
Lynchburg	681	153	188	29.38	30.11	+ .10	73.4	− 0.1	96	1	83	50	30	64	32		67	64	77	7.61	+ 3.7	15	3,629	e.	34	nw.	21	10	13	7	5.1	.....	.....
Norfolk	91	170	205	30.02	30.12	+ .12	73.4	− 1.0	92	7	82	58	30	65	31		66	62	74	3.48	− 0.8	5	7,943	ne.	67	nw.	7	12	13	5	4.5	.....	.....
Richmond	144	11	52	29.96	30.13	+ .12	73.2	− 1.9	89	7	83	50	30	64	30		67	65	79	3.90	+ 0.4	10	3,911	se.	24	n.	10	5	9	16	6.9	.....	.....
Wytheville	2,293	49	55	27.78	30.09	+ .08	68.7	0.0	86	1	79	49	30	59	30		63	60	81	3.98	− 0.1	16	2,701	e.	25	sw.	8	9	16	5	4.7	.....	.....
South Atlantic States.							**75.5**	**− 0.6**											**78**	**5.95**	**+ 1.0**									**5.9**		
Asheville	2,255	70	84	27.80	30.10	+ .09	70.3	+ 1.6	86	7	80	55	7	61	31		64	61	81	4.05	− 0.3	15	4,379	se.	34	nw.	8	6	19	5	5.3	.....	.....
Charlotte	773	153	161	29.26	30.08	+ .07	75.8	+ 0.3	94	7	85	57	30	67	26		68	64	72	2.43	− 2.0	10	3,066	ne.	26	sw.	8	3	17	10	6.2	.....	.....
Hatteras	11	12	50	30.08	30.10	+ .09	72.8	− 1.6	86	7	78	62	13	68	15		68	66	80	9.76	+ 5.4	4	9,570	ne.	44	n.	28	8	13	9	5.6	.....	.....
Raleigh	376	103	110	29.70	30.09	+ .08	74.4	− 0.7	94	1	84	52	30	65	28		67	64	74	2.22	− 2.5	11	4,750	se.	38	nw.	8	5	16	9	6.1	.....	.....
Wilmington	78	81	91	30.00	30.09	+ .08	74.0	− 1.5	92	21	82	57	30	66	28		68	66	80	4.25	− 1.4	13	5,140	e.	28	n.	8	12	9	9	5.1	.....	.....
Charleston	48	11	92	30.01	30.06	+ .05	77.4	− 1.1	92	21	83	64	14	72	22		71	69	77	6.33	+ 0.9	10	7,981	e.	44	ne.	4	11	5	14	5.8	.....	.....
Columbia, S. C	351	41	57	29.70	30.07	+ .06	77.6	− 0.6	96	21	87	58	14	68	31		69	65	72	2.65	− 1.5	9	4,213	e.	21	e.	11	7	11	12	6.1	.....	.....
Augusta	180	62	77	29.86	30.05	+ .04	78.0	− 0.1	95	8	87	59	14	69	30		71	69	79	7.05	+ 2.5	10	3,698	e.	44	nw.	8	5	9	16	6.8	.....	.....
Savannah	65	150	194	.....	30.05	+ .04	77.2	− 1.0	92	21	84	64	30	71	23		.....	.....	82	6.98	+ 1.0	14	7,293	e.	32	e.	2	10	4	16	.....	.....	.....
Jacksonville	43	200	245	29.98	30.03	+ .02	77.4	− 1.6	93	22	83	66	15	72	22		72	71	83	13.79	+ 8.3	15	7,941	ne.	39	e.	25	8	10	12	6.1	.....	.....
Greenville, S. C	1,013	113	122	28.99	30.06	.....	75.3	.....	93	21	84	59	30	67	28		67	64	74	3.99	.....	12	4,992	ne.	33	n.	8	3	18	9	6.2	.....	.....
Florida Peninsula.							**79.7**	**− 1.1**											**78**	**8.74**	**+ 1.9**									**7.3**		
Key West	22	10	64	29.96	29.98	− .01	80.5	− 1.7	89	30	85	71	19	76	15		75	73	80	11.04	+ 6.8	16	5,928	e.	34	se.	12	4	13	13	6.6	.....	.....
Miami	25	71	79	29.98	30.01	.....	79.0	− 1.4	89	28	84	68	16	74	15		74	71	77	7.26	− 0.6	14	5,381	e.	25	ne.	14	1	11	18	7.8	.....	.....
Tampa	35	79	92	29.97	30.00	− .01	79.7	− 0.3	93	17	88	66	15	72	22		72	70	77	7.93	−.0.4	15	4,554	ne.	36	ne.	12	0	13	17	7.5	.....	.....
East Gulf States.							**78.3**	**+ 0.2**											**77**	**4.06**	**− 0.5**									**6.1**		
Atlanta	1,174	190	216	28.86	30.07	+ .06	76.8	+ 1.2	93	15	85	63	30	68	23		68	65	73	2.08	− 1.8	16	6,445	e.	42	se.	12	5	8	17	6.8	.....	.....
Macon	370	78	87	29.66	30.05	+ .04	77.6	+ 0.5	94	8	87	58	14	68	30		70	66	74	2.52	− 1.1	14	3,847	e.	28	nw.	27	5	13	12	6.3	.....	.....
Thomasville	273	49	58	29.73	30.02	+ .02	78.6	− 0.9	94	22	87	65	14	70	24		71	68	76	6.38	+ 1.7	15	3,195	ne.	21	e.	17	4	16	10	6.4	.....	.....
Pensacola	56	149	185	29.95	30.01	+ .02	78.4	−.1.6	89	7	83	68	29	74	15		73	71	79	2.24	− 2.6	9	8,632	s.	42	e.	12	7	12	11	6.0	.....	.....
Anniston	741	9	57	29.28	30.06	+ .06	77.0	+ 2.0	95	15	87	60	14	67	32		.....	.....	.....	3.56	− 0.3	15	3,256	e.	24	e.	10	8	18	4	5.2	.....	.....
Birmingham	700	11	48	29.30	30.05	+ .06	78.2	0.0	95	16	87	65	6	69	29		69	66	75	3.30	− 0.6	13	3,908	e.	24	s.	8	10	10	10	5.6	.....	.....
Mobile	57	125	161	29.95	30.01	+ .02	80.0	+ 0.9	96	16	87	67	11	73	26		73	71	78	2.12	− 3.8	8	5,925	e.	32	e.	12	5	11	14	6.5	.....	.....
Montgomery	223	100	112	29.79	30.03	+ .03	79.7	+ 0.6	95	15	88	64	14	71	29		71	67	71	3.34	− 0.9	9	4,040	e.	29	se.	9	8	12	10	5.5	.....	.....
Corinth	469	6	.....	.....	.....	.....	78.8	.....	96	17	89	58	5	68	29		.....	.....	.....	5.84	.....	14	.....	se.	.....	.....	.....	6	19	5	.....	.....	.....
Jackson	304	5	.....	.....	.....	.....	78.8	.....	98	17	89	56	5	68	33		.....	.....	.....	5.12	.....	13	.....	se.	.....	.....	.....	7	17	6	.....	.....	.....
Meridian	375	85	93	29.63	30.01	+ .03	77.4	+ 0.1	95	17	86	59	15	68	30		71	68	78	8.81	+ 4.2	12	3,170	e.	33	e.	12	7	16	7	5.6	.....	.....
Vicksburg	247	65	74	29.74	30.01	+ .04	78.1	− 0.4	95	17	86	58	4	70	25		71	69	81	5.85	+ 1.4	13	3,890	se.	23	s.	25	5	7	18	6.5	.....	.....
New Orleans	51	76	84	29.94	29.98	.00	80.0	− 0.4	92	29	86	70	4	74	20		74	72	81	4.50	− 1.7	13	4,443	se.	24	se.	20	1	18	11	6.5	.....	.....
West Gulf States.							**77.0**	**− 2.0**											**79**	**6.23**	**+ 2.5**									**5.9**		
Shreveport	249	77	93	29.73	29.99	+ .03	77.8	− 1.8	95	17	87	57	4	69	24		70	68	80	5.53	+ 2.0	15	4,177	s.	27	se.	9	6	16	8	5.7	.....	.....
Bentonville	1,303	11	44	28.64	29.98	+ .03	73.5	− 0.6	90	18	83	49	4	64	28		.....	.....	.....	6.83	+ 2.3	16	2,390	se.	23	s.	4	7	17	6	5.5	.....	.....
Fort Smith	457	79	94	29.51	29.98	+ .04	77.4	+ 0.6	94	26	86	53	4	68	30		71	68	78	2.49	− 1.5	12	4,257	e.	42	nw.	6	6	11	13	6.3	.....	.....
Little Rock	357	139	147	29.63	30.00	+ .04	77.2	0.0	92	16	85	54	4	69	25		70	67	77	2.75	− 1.3	11	4,682	e.	42	n.	6	7	11	12	6.0	.....	.....
Brownsville	57	4	26	.....	.....	.....	82.6	.....	96	14	92	56	3	73	30		.....	.....	.....	5.08	.....	8	.....	se.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	29.92	29.94	+ .03	79.3	− 1.3	91	24	84	56	3	74	24		74	72	82	3.33	+ 0.6	14	8,592	se.	39	se.	9	4	16	10	5.9	.....	.....
Dallas	512	109	117	29.43	29.97	.....	77.6	.....	94	17	86	53	3	69	27		.....	.....	.....	1.42	.....	9	5,735	se.	39	se.	9	6	17	7	5.3	.....	.....
Fort Worth	670	106	114	29.24	29.94	+ .02	76.7	− 3.4	94	7	86	52	3	68	28		69	66	76	3.72	+ 0.8	8	5,704	se.	38	se.	9	7	12	11	5.8	.....	.....
Galveston	54	106	114	29.92	29.98	+ .03	77.4	− 3.5	86	17	82	59	3	73	17		73	71	83	15.49	+10.7	11	7,839	se.	38	s.	25	7	10	13	6.0	.....	.....
Houston	138	111	121	29.81	29.95	.....	77.6	− 3.4	91	17	85	57	3	70	26		.....	.....	.....	15.85	.....	13	5,310	se.	30	se.	9	10	8	12	5.3	.....	.....
Palestine	510	64	72	29.46	29.98	+ .04	76.3	− 2.1	92	17	85	53	3	68	25		70	67	81	6.33	+ 2.3	15	4,138	ne.	24	se.	23	8	6	16	6.3	.....	.....
Port Arthur	34	58	66	29.92	29.96	.....	77.2	.....	88	17	83	61	3	72	20		72	70	82	7.71	.....	17	6,609	e.	38	e.	11	4	11	15	6.9	.....	.....
San Antonio	701	119	132	29.23	29.94	+ .04	77.5	− 2.9	92	6	86	48	3	68	32		70	67	78	7.01	+ 3.9	14	5,557	se.	30	s.	9	5	13	12	6.2	.....	.....
Taylor	582	55	63	29.37	29.98	+ .06	76.3	− 3.7	92	6	85	49	3	67	30		.....	.....	.....	8.84	+ 5.3	11	5,246	se.	31	nw.	2	5	12	13	6.4	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, June, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.						Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.						
Ohio Valley and Tennessee.	*Ft.*	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.* 76.1	° *F.* 3.1	° *F*		° *F*	° *F*		° *F*	° *F*		° *F*	° *F*	% 72	*In* 4.00	*In.* −0.2		*Miles*								*0–10* 5.2	*In.*	*In.*
Chattanooga	762	189	213	29.27	30.06	+ .06	77.4	+ 2.0	93	17	86	63	7	68	26		68	64	69	2.27	− 2.0	12	4,343	s.	36	sw.	23	4	19	7	5.5	.....	.....
Knoxville	996	102	111	29.02	30.05	+ .05	76.7	+ 3.3	93	21	86	59	8	67	28		68	65	71	5.54	+ 1.4	9	3,533	ne.	32	ne.	21	7	15	8	5.7	.....	.....
Memphis	399	76	97	29.63	30.04	+ .07	78.8	+ 1.1	95	17	86	61	4	71	21		71	69	77	5.64	+ 1.3	13	4,460	e.	44	nw.	23	11	6	13	5.5	.....	.....
Nashville	546	168	191	29.48	30.06	+ .07	78.2	+ 1.9	94	17	87	63	9	69	26		69	66	71	3.96	− 0.4	8	5,113	se.	43	nw.	9	9	16	5	5.1	.....	.....
Lexington	989	193	230	29.02	30.07	+ .07	76.4	+ 3.2	93	11	85	59	29	68	24		.....	.....	.....	4.49	+ 0.5	14	7,109	sw.	38	se.	11	10	13	7	5.0	.....	.....
Louisville	525	219	255	29.49	30.06	+ .08	77.8	+ 2.8	92	16	87	58	29	69	27		69	66	71	4.41	+ 0.2	13	6,183	sw.	40	ne.	27	12	15	3	4.4	.....	.....
Evansville	431	139	175	29.58	30.04	+ .07	78.2	+ 2.9	94	12	88	61	6	69	25		70	67	72	6.75	+ 2.6	13	6,105	sw.	67	s.	2	5	22	3	5.4	.....	.....
Indianapolis	822	194	230	29.18	30.05	+ .08	75.8	+ 3.4	92	18	85	52	29	67	33		68	64	71	3.33	− 1.0	9	6,566	se.	36	se.	12	7	16	7	5.1	.....	.....
Terre Haute	575	96	129	29.42	30.03	.....	76.2	.....	92	18	85	57	29	67	28		69	65	73	5.04	.....	10	5,374	s.	35	nw.	6	0	25	5	6.1	.....	.....
Cincinnati	628	11	51	29.39	30.06	+ .07	75.3	+ 3.6	91	14	85	54	29	66	28		68	64	72	2.44	− 1.5	10	3,739	s.	25	ne.	16	8	14	8	5.2	.....	.....
Columbus	824	173	222	29.21	30.07	+ .08	75.6	+ 4.6	91	1	85	56	29	66	26		68	65	72	1.76	− 1.7	8	6,568	se.	30	w.	7	6	13	11	5.6	.....	.....
Dayton	899	181	216	29.09	30.02	.....	75.6	+ 3.4	94	1	85	54	29	66	29		67	63	71	2.59	− 1.4	11	5,369	sw.	50	ne.	16	10	14	6	4.8	.....	.....
Pittsburgh	842	333	410	29.20	30.08	+ .09	75.0	+ 3.9	92	1	84	52	29	66	25		65	60	64	3.58	− 0.3	10	6,364	se.	38	ne.	20	12	12	6	4.4	.....	.....
Elkins	1,940	41	50	.....	30.10	+ .10	69.0	+ 2.4	89	1	81	45	29	57	37		.....	.....	78	6.40	+ 1.4	14	2,674	s.	32	se.	14	2	16	12	.....	.....	.....
Parkersburg	638	77	84	29.45	30.10	+ .10	76.0	+ 4.5	93	14	86	57	29	66	27		67	63	70	2.80	− 1.8	11	2,954	se.	22	nw.	7	11	8	11	5.3	.....	.....
Lower Lake Region.							72.6	+5.6											69	2.61	−0.9										3.7		
Buffalo	767	247	280	29.28	30.09	+ .12	72.4	+7.3	94	3	80	48	29	65	27		65	61	69	0.54	−2.6	5	8,068	sw.	37	sw.	5	15	11	4	4.1	.....	.....
Canton	448	10	61	29.62	30.09	.....	69.4	+3.6	97	4	80	42	22	59	32		.....	.....	.....	4.83	+1.4	10	5,528	sw.	31	e.	20	24	3	3	2.3	.....	.....
Oswego	335	76	91	29.73	30.09	+ .12	69.6	+5.8	87	4	77	48	29	62	23		64	60	73	4.40	+1.0	8	5,373	s.	30	ne.	27	16	6	8	4.0	.....	.....
Rochester	523	97	113	29.55	30.11	+ .14	72.8	+6.7	93	3	82	50	29	64	31		65	60	68	2.96	−0.2	8	4,456	sw.	19	w.	26	19	6	5	3.4	.....	.....
Syracuse	597	97	113	29.48	30.13	+ .16	71.4	+4.5	95	4	81	45	29	62	29		.....	.....	.....	1.59	−2.3	9	5,742	s.	39	ne.	20	15	10	5	4.4	.....	.....
Erie	714	130	166	29.32	30.08	+ .10	73.1	+6.1	92	4	81	49	29	65	23		65	60	65	3.07	−0.7	9	7,606	ne.	34	ne.	28	17	10	3	3.5	.....	.....
Cleveland	762	190	201	29.27	30.08	+ .10	73.4	+5.5	91	3	80	52	29	67	20		66	61	67	1.24	−2.4	6	7,397	ne.	39	ne.	28	14	12	4	4.1	.....	.....
Sandusky	629	62	103	29.40	30.07	+ .09	74.1	+5.3	91	19	81	55	29	67	20		.....	.....	.....	0.91	−2.9	5	6,851	e.	26	ne.	21	15	10	5	3.8	.....	.....
Toledo	628	208	243	29.40	30.08	+ .11	74.4	+5.0	94	1	83	50	28	66	24		66	63	70	2.93	−0.4	8	7,589	sw.	45	sw.	19	15	10	5	3.6	.....	.....
Fort Wayne	856	113	124	29.16	30.07	.....	74.5	+6.0	93	19	84	51	28	65	31		66	62	70	2.23	.....	11	4,659	ne.	31	sw.	2	11	15	4	4.5	.....	.....
Detroit	730	218	245	29.31	30.08	+ .11	74.0	+6.2	92	19	82	49	28	66	23		66	63	71	3.61	−0.3	8	6,486	e.	38	se.	5	17	10	3	3.1	.....	.....
Upper Lake Region.							68.4	+5.9											75	2.51	−0.8										4.1		
Alpena	609	13	92	29.45	30.12	+ .16	67.0	+6.7	91	14	74	44	29	60	23		63	60	76	3.78	+0.2	8	6,214	se.	30	nw.	26	13	11	6	4.5	.....	.....
Escanaba	612	54	60	29.43	30.09	+ .15	66.6	+6.0	87	14	74	44	28	60	21		62	60	81	4.45	+0.8	8	6,241	s.	30	ne.	27	16	12	2	3.1	.....	.....
Grand Haven	632	54	92	29.39	30.06	+ .10	72.0	+7.3	90	18	81	47	28	63	32		65	61	71	1.07	−1.4	5	5,680	e.	44	s.	2	11	14	5	4.6	.....	.....
Grand Rapids	707	70	87	29.32	30.07	+ .10	74.2	+6.1	94	2	84	49	29	64	32		66	61	66	1.84	−0.7	9	3,687	se.	19	se.	11	9	17	4	5.2	.....	.....
Houghton	684	62	99	29.35	30.07	+ .13	64.3	+4.9	92	13	74	42	28	54	32		.....	.....	.....	3.41	−0.1	12	6,308	e.	30	nw.	25	7	13	10	5.8	.....	.....
Lansing	878	11	62	29.14	30.07	.....	71.9	+4.5	93	1	84	44	29	60	34		66	63	76	3.18	−0.2	10	2,886	se.	25	sw.	19	9	15	6	4.7	.....	.....
Ludington	637	60	66	29.38	30.06	.....	69.2	.....	87	21	78	43	28	61	28		64	60	71	2.47	.....	9	5,270	e.	30	s.	2	5	13	12	6.2	.....	.....
Marquette	734	77	111	29.32	30.12	+ .18	62.3	+3.8	92	18	72	40	28	52	39		57	54	78	2.01	−1.5	10	5,184	nw.	29	sw.	2	5	13	12	6.2	.....	.....
Port Huron	638	70	120	29.40	30.08	+ .11	71.8	+8.0	92	2	80	51	29	63	28		65	61	72	1.11	−2.1	8	6,055	ne.	44	nw.	13	14	15	1	3.5	.....	.....
Saginaw	641	48	82	29.39	30.08	.....	73.6	.....	94	1	84	47	29	63	36		66	62	70	2.83	+0.2	5	5,125	se.	32	s.	11	14	15	1	3.6	.....	.....
Sault Sainte Marie	614	11	61	29.43	30.11	+ .15	67.3	+9.7	92	1	79	43	28	55	38		61	57	74	2.16	−0.6	4	3,843	se.	22	ne.	26	14	11	5	4.3	.....	.....
Chicago	823	140	310	29.19	30.06	+ .10	72.6	+6.3	88	14	78	55	28	67	17		66	63	73	3.16	−0.5	15	6,710	n.	31	s.	12	10	16	4	4.5	.....	.....
Green Bay	617	109	144	29.40	30.05	+ .10	71.2	+6.1	90	18	80	51	28	62	30		64	61	74	0.83	−2.7	11	6,754	se.	39	nw.	10	6	13	11	6.2	.....	.....
Milwaukee	681	119	133	29.32	30.06	+ .11	69.7	+6.2	88	14	76	56	5	64	20		64	62	79	1.49	−2.2	10	6,138	se.	36	se.	28	9	16	5	4.9	.....	.....
Duluth	1,133	11	47	28.86	30.07	+ .15	58.1	+0.4	85	18	66	41	28	50	32		56	55	91	3.77	−0.8	17	7,704	ne.	41	ne.	10	7	9	14	6.5	.....	.....
North Dakota.							68.4	+4.7											69	2.34	−1.3										3.9		
Moorhead	940	8	57	29.01	30.01	+ .11	69.0	+4.7	90	25	79	38	3	60	29		64	62	80	2.50	−1.6	10	6,207	se.	30	se.	29	17	7	6	3.2	.....	.....
Bismarck	1,674	8	57	28.23	29.98	+ .11	69.0	+4.8	98	24	81	35	2	57	33		61	56	66	0.63	−2.9	5	8,460	se.	63	sw.	12	9	15	6	4.8	.....	.....
Devils Lake	1,482	11	44	28.43	29.98	+ .10	66.1	+3.5	90	17	77	36	2	56	31		61	57	74	3.58	0.0	7	7,642	se.	34	s.	13	13	10	7	4.7	.....	.....
Ellendale	1,457	10	56	28.44	29.99	.....	66.6	.....	90	25	76	37	3	58	28		63	60	80	2.91	.....	8	10,405	s.	44	ne.	17	7	13	10	6.1	.....	.....
Grand Forks	835	12	89	.....	.....	.....	67.1	.....	90	30	77	39	3	58	28		63	.....	.....	2.39	.....	7	.....	se.	30	se.	28	11	11	8	.....	.....	.....
Williston	1,872	41	48	27.97	29.90	+ .04	69.4	+5.9	99	29	83	33	2	56	44		58	51	55	2.64	−0.9	4	8,080	se.	60	w.	29	19	11	0	2.9	.....	.....
Upper Mississippi Valley.							74.0	+3.1											76	4.78	+0.4										5.6		
Minneapolis	918	10	208	29.02	29.99	.....	70.2	.....	91	18	78	49	6	62	24		.....	.....	.....	4.04	0.0	13	7,633	se.	39	w.	22	5	7	18	7.3	.....	.....
St. Paul	837	201	236	29.12	30.01	+ .09	70.0	+2.6	92	19	78	50	6	62	23		.....	.....	.....	4.40	0.0	12	7,721	se.	47	se.	23	4	17	9	6.1	.....	.....
La Crosse	714	11	48	29.26	30.01	+ .08	71.5	+3.3	90	19	81	51	29	62	30		.....	.....	.....	6.52	+2.1	15	2,636	se.	30	sw.	10	5	8	17	6.6	.....	.....
Madison	974	70	78	29.03	30.05	+ .11	71.2	+3.9	90	19	80	50	28	63	27		65	62	79	3.35	−0.8	13	5,213	se.	33	sw.	11	5	10	15	6.9	.....	.....
Wausau	1,247	4	.....	28.74	30.04	.....	69.1	.....	88	18	78	44	28	60	29		.....	.....	.....	4.80	.....	14	.....	se.	.....	.....	.....	.....	.....	.....	11	12	6.0	.....	.....
Charles City	1,015	10	49	28.96	30.02	+ .11	70.6	+1.8	90	19	80	51	6	62	28		65	63	82	6.05	+1.0	14	3,954	se.	20	ne.	18	5	18	7	5.7	.....	.....
Davenport	606	71	79	29.37	30.02	+ .08	74.6	+3.7	92	16	84	52	28	65	28		67	64	73	3.90	−0.2	11	4,664	e.	30	s.	3	8	15	7	5.1	.....	.....
Des Moines	861	84	97	29.11	30.00	+ .08	73.4	+3.0	92	25	82	52	2	64	24		67	64	78	7.36	+2.4	13	4,536	sw.	26	s.	13	5	12	13	6.3	.....	.....
Dubuque	698	81	96	29.31	30.04	+ .11	72.8	+3.2	92	19	82	52	28	64	26		67	64	78	6.24	+1.7	15	3,985	se.	24	se.	1	7	16	7	5.5	.....	.....
Keokuk	614	64	78	29.36	30.02	+ .08	75.8	+3.3	93	19	85	56	28	67	26		68	65	72	2.38	−2.0	7	4,239	se.	25	se.	11	10	17	3	4.2	.....	.....
Cairo	356	87	93	29.64	30.01	+ .04	78.0	+2.8	93	17	86	62	7	70	25		71	69	79	4.61	+0.3	11	4,749	se.	59	sw.	8	6	13	11	6.1	.....	.....
Peoria	609	11	45	29.38	30.05	+ .10	74.8	+3.9	92	13	85	55	28	65	29		68	65	79	3.96	−0.3	9	3,249	se.	21	ne.	20	13	8	9	4.8	.....	.....
Springfield, Ill.	644	10	91	29.34	30.00	+ .05	76.0	+3.7	92	24	86	56	6	66	24		68	66	75	5.46	+1.2	9	4,473	se.	31	sw.	2	7	16	7	5.5	.....	.....
Hannibal	534	74	109	29.43	30.00	+ .05	76.0	+2.7	94	17	85	57	7	67	25		.....	.....	.....	3.41	−0.1	12	4,723	sw.	43	ne.	18	12	15	3	4.2	.....	.....
St. Louis	567	265	308	29.41	30.01	+ .06	77.3	+2.2	92	25	86	60	5	68	23		69	65	70	5.30	+0.8	12	7,552	s.	69	sw.	16	9	19	2	4.3	.....	.....
Missouri Valley.							72.5	+ 1.6											76	4.29	0.0										5.9		
Columbia, Mo.	781	11	84	29.17	29.98	+ .03	75.1	+ 0.6	91	24	84	53	4	66	24		.....	.....	.....	3.96	− 0.4	12	4,178	se.	33	ne.	24	10	17	3	4.6	.....	.....
Kansas City	963	161	181	28.96	29.97	+ .05	75.2	+ 2.2	97	25	84	50	4	66	24		67	63	71	5.09	+ 0.4	12	6,370	s.	50	n.	26	11	15	4	4.8	.....	.....
St. Joseph	967	11	49	28.96	29.97	.....	75.0	.....	96	24	85	51	2	65	25		67	64	75	4.97	.....	13	4,668	se.	54	nw.	26	11	15	4	4.2	.....	.....
Springfield, Mo	1,324	98	104	28.63	30.01	+ .06	73.6	+ 1.3	89	25	82	50	4	65	23		67	64	78	4.00	− 1.2	14	5,788	se.	37	se.	26	15	11	4	3.7	.....	.....
Iola	984	11	50	28.94	29.96	+ .03	74.6	+ 1.2	94	25	85	47	4	64	31		.....	.....	.....	4.21	− 0.5	19	3,447	se.	25	nw.	1	10	11	9	5.4	.....	.....
Topeka	983	85	101	.....	.....	.....	74.0	+ 0.5	98	25	84	48	4	64	29		.....	.....	.....	3.93	+ 0.9	14	5,632	se.	39	n.	26	6	20	4	5.0	.....	.....
Drexel	1,299	10	54	28.64	29.94	.....	70.9	.....	94	23	80	47	2	62	31		66	64	81	7.79	.....	15	6,228	s.	56	e.	19	9	9	12	5.4	.....	.....
Lincoln	1,189	11	84	28.72	29.96	+ .06	73.0	+ 1.4	97	23	82	48	5	64	27		66	63	75	4.99	+ 0.7	13	6,008	s.	33	ne.	25	8	14	10	5.9	.....	.....
Omaha	1,105	115	122	28.82	29.97	+ .06	73.4	+ 1.8	98	23	82	48	2	65	32		67	64	76	4.44	− 0.6	14	5,030	s.	42	nw.	25	8	16	6	5.4	.....	.....
Valentine	2,598	47	54	27.29	29.96	+ .10	69.2	+ 2.1	100	23	81	35	3	58	34		61	57	70	2.17	− 1.6	9	8,090	s.	32	s.	29	16	8	6	4.2	.....	.....
Sioux City	1,135	94	164	28.79	29.98	+ .08	71.4	+ 2.0	96	23	80	48	3	63	26		65	63	79	6.06	+ 2.2	15	7,769	se.	39	n.	19	4	13	13	6.6	.....	.....
Huron	1,306	59	74	28.62	29.99	+ .11	68.9	+ 2.3	92	22	77	39	3	61	25		64	62	79	5.98	+ 2.2	10	7,452	se.	36	s.	30	9	9	12	5.9	.....	.....
Pierre	1,572	70	75	28.30	29.93	+ .06	71.0	+ 2.1	100	30	80	39	3	62	27		64	60	73	2.55	− 0.5	11	7,089	se.	54	ne.	26	15	2	13	4.7	.....	.....
Yankton	1,233	49	57	28.68	29.96	+ .07	70.7	+ 1.3	93	25	79	48	2	63	25		.....	.....	.....	4.04	− 0.2	11	5,184	s.	24	s.	30	7	9	14	6.6	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, June, 1919*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.												Mean wet thermometer.	Mean temperature of the dew-point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.						Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity: Miles per hour.	Maximum velocity: Direction.	Maximum velocity: Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	° *F.*	° *F.*	° *F*		° *F*	° *F*		° *F*	° *F*	° *F*	° *F*	° *F*	*U*	*In*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope.							**65.8**	**+ 3.7**											**50**	**1.33**	**− 0.9**										**3.5**		
Billings	3,140	5					69.2		106	27	88	32	2	51	53					0.36		4		ne.									
Havre	2,505	11	44	27.32	29.90	+ .05	67.6	+ 5.2	100	21	82	33	2	53	40	54	45	54		1.68	− 1.1	9	4,868	e.	38	nw.	16	19	9	2	3.0		
Helena	4,110	87	114	25.78	29.89	+ .01	65.6	+ 5.0	98	21	79	35	1	52	37	51	40	46		0.32	− 1.8	6	6,008	sw.	44	se.	20	13	10	7	4.4	T.	
Kalispell	2,962	11	34	26.90	29.91	+ .02	60.2	+ 1.4	95	20	75	33	1	45	42	47	34	44		0.55	− 1.2	3	4,174	nw.	39	w.	2	16	11	3	3.6		
Miles City	2,371	26	48	27.42	29.90	+ .05	74.4	+ 8.4	107	28	88	34	2	61	39	59	49	48		0.46	− 2.3	3	5,503	e.	32	nw.	12	16	14	0	3.0		
Rapid City	3,259	50	58	26.62	29.97	+ .12	67.3	+ 3.5	99	28	80	35	3	54	36	57	50	55		3.60	0.0	8	6,522	se.	44	s.	28	14	11	5	4.2		
Cheyenne	6,088	84	101	24.07	29.93	+ .09	62.6	+ 1.1	90	28	77	28	3	48	38	48	38	48		0.72	− 0.8	8	7,649	w.	44	s.	14	11	16	3	4.5	1.6	
Lander	5,372	60	68	24.66	29.89	+ .04	66.1	+ 4.8	96	22	83	33	2	50	44	48	33	37		0.34	− 0.8	3	4,564	sw.	40	se.	18	19	9	2	3.3		
Sheridan	3,790	10	47	26.08	29.90	.....	68.0	.....	103	28	86	30	2	50	53	55	46	52		0.54	.....	5	4,700	se.	36	se.	25	23	5	2	2.7		
Yellowstone Park	6,200	11	48	23.92	29.90	+ .04	59.3	+ 3.3	88	25	75	28	1	43	41	45	32	44		0.14	− 1.5	3	5,675	s.	35	s.	29	19	9	2	2.7		
North Platte	2,821	11	51	27.11	29.99	+ .13	69.3	+ 0.9	97	25	81	38	2	58	39	61	58	74		4.15	+ 0.9	11	5,428	se.	28	n.	1	20	3	7	3.5		
Middle Slope.							**71.2**	**− 0.7**											**67**	**2.85**	**− 0.3**										**4.8**		
Denver	5,292	106	113	24.77	29.94	+ .10	67.7	+ 1.3	96	30	82	32	1	54	36	52	41	48		0.28	− 1.2	3	5,581	s.	36	n.	4	11	16	3	4.5	0.4	
Pueblo	4,685	80	86	25.33	29.94	+ .11	68.4	− 0.6	96	30	84	32	2	53	39	54	44	52		1.39	− 0.1	4	4,789	nw.	39	w.	25	18	9	3	3.5		
Concordia	1,392	50	58	28.52	29.97	+ .07	72.8	+ 0.1	99	24	83	47	1	63	30	66	62	75		6.14	+ 1.2	13	4,867	s.	30	ne.	28	6	15	9	5.6		
Dodge City	2,509	11	51	27.39	29.94	+ .07	70.7	− 2.4	94	24	81	42	2	60	33	63	59	72		1.72	− 1.6	9	6,422	se.	32	nw.	1	16	8	6	3.8		
Wichita	1,358	139	158	28.57	29.97	+ .06	73.6	− 0.7	95	26	83	46	4	64	28	66	63	76		2.68	− 2.1	7	7,088	s.	38	s.	10	9	14	7	5.1		
Altus	1,410	5	.....	.....	.....	.....	75.2	.....	95	6	86	44	3	64	37	.....	.....	.....		3.93	.....	9	.....	e.	.....	.....	.....	6	9	15	.....	.....	.....
Muskogee	652	4	.....	.....	.....	.....	77.3	.....	96	17	89	50	5	66	34	.....	.....	.....		6.31	.....	14	.....	e.	.....	.....	.....	10	14	6	.....	.....	.....
Oklahoma	1,214	10	47	28.72	29.98	+ .07	73.8	− 1.9	93	27	83	48	5	65	29	67	64	78		4.87	+ 1.8	14	6,846	s.	43	sw.	7	3	16	11	6.4		
Southern Slope.							**73.1**	**− 4.1**											**69**	**2.84**	**+ 0.2**										**4.8**		
Abilene	1,738	10	5	28.18	29.96	+ .08	74.6	− 3.6	96	7	85	44	3	64	34	66	62	74		3.12	0.0	17	5,325	s.	32	nw.	3	6	11	13	6.2		
Amarillo	3,676	10	4	26.32	29.99	+ .14	68.9	− 3.1	90	7	80	39	2	58	35	61	57	72		2.94	0.0	10	6,561	se.	42	sw.	11	11	19	0	4.5		
Del Rio	944	64	71	28.94	29.91	+ .06	78.5	− 3.6	93	7	88	49	3	69	29	.....	.....	.....		1.30	− 1.1	10	7,150	se.	39	s.	8	6	21	3	5.0		
Roswell	3,566	75	85	26.37	26.91	+ .11	70.3	− 6.0	92	24	83	43	2	57	39	59	53	61		4.02	+ 1.9	11	4,660	s.	36	w.	12	13	16	1	3.4		
Southern Plateau.							**74.2**	**− 0.4**											**35**	**0.35**	**0.0**										**1.7**		
El Paso	3,762	110	133	26.15	29.81	+ .06	77.6	− 2.0	97	24	90	46	3	65	34	58	44	38		0.27	− 0.3	2	7,776	se.	53	ne.	13	27	3	0	2.1		
Santa Fe	7,013	57	66	23.32	29.87	+ .06	63.1	− 3.1	87	22	76	33	1	50	34	51	44	57		1.50	+ 0.5	11	5,122	e.	31	se.	11	8	21	1	4.5	T.	
Flagstaff	6,908	8	57	23.40	29.84	+ .06	59.7	+ 0.4	89	22	78	30	3	41	49	43	.....	.....		T.	.....	0	.....	w.	42	w.	5	26	4	0	.....	.....	.....
Phoenix	1,108	76	81	28.62	29.74	.00	85.4	+ 1.0	113	26	103	56	2	68	47	60	39	24		T.	− 0.1	0	4,002	w.	25	se.	29	28	2	0	0.7		
Yuma	141	9	54	29.60	29.74	.00	86.4	+ 1.7	116	26	104	59	3	69	44	63	46	33		0.00	0.0	0	3,902	w.	28	n.	1	30	0	0	0.0		
Independence	3,910	11	42	25.90	29.86	+ .08	73.0	− 0.4	97	25	90	48	12	56	41	50	26	22		T.	− 0.1	0	4,571	nw.	27	sw.	6	25	5	0	1.2		
Needles	488	4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....		.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Middle Plateau.							**67.9**	**+ 2.2**											**28**	**0.03**	**− 0.4**										**1.3**		
Reno	4,532	74	81	25.45	29.88	+ .02	62.8	+ 1.8	92	23	80	33	1	46	45	46	31	37		T.	− 0.2	0	5,870	w.	33	w.	13	27	3	0	1.0		
Tonopah	6,090	12	20	24.04	29.83	.....	67.2	.....	88	27	79	39	1	55	30	46	24	21		T.	− 0.4	0	5,738	se.	27	se.	6	29	1	0	0.6		
Winnemucca	4,344	18	56	25.58	29.90	+ .02	64.2	+ 0.9	94	24	82	34	1	46	47	46	28	33		0.00	− 0.6	0	4,509	sw.	24	sw.	13	27	1	2	1.5		
Modena	5,479	10	43	24.60	29.85	+ .03	64.3	+ 1.1	93	23	84	35	1	44	47	43	17	20		0.13	− 0.3	1	9,971	sw.	51	sw.	10	28	2	0	1.0		
Salt Lake City	4,360	163	203	25.55	29.82	− .03	74.0	+ 5.7	98	24	86	37	1	62	34	54	38	32		T.	− 0.8	0	6,699	se.	44	se.	11	28	2	0	0.9		
Grand Junction	4,602	82	96	25.36	29.86	+ .03	74.2	+ 1.6	98	28	89	35	1	60	37	51	30	24		0.06	− 0.3	1	5,249	se.	30	sw.	11	21	7	2	2.7		
Northern Plateau.							**64.9**	**0.0**											**37**	**0.03**	**− 1.1**										**3.4**		
Baker	3,471	48	53	26.44	29.98	+ .03	59.0	+ 0.4	93	19	75	32	11	43	44	46	35	43		T.	− 1.2	0	4,538	w	21	n.	2	17	7	6	3.9		
Boise	2,739	78	86	27.10	29.91	.00	66.4	+ 0.4	100	19	82	36	1	50	41	50	36	39		T.	− 0.9	0	3,929	nw	21	w.	3	19	10	1	2.9		
Lewiston	757	40	48	29.18	29.99	+ .05	66.6	− 2.5	99	19	82	38	11	51	46	.....	.....	.....		0.13	− 0.9	3	3,043	e.	28	w.	2	15	11	4	4.1		
Pocatello	4,477	60	68	25.43	29.84	− .03	68.5	+ 4.3	96	25	84	33	1	53	40	48	27	25		T.	− 1.0	0	6,422	se.	28	sw.	26	22	7	1	2.0		
Spokane	1,929	101	110	27.95	29.98	+ .04	62.4	− 1.0	96	19	76	36	1	48	44	48	34	41		0.01	− 1.6	1	4,749	sw.	36	w.	2	10	16	4	4.4		
Walla Walla	991	57	65	28.93	29.99	+ .03	66.4	− 1.8	93	18	80	46	12	53	41	51	38	39		0.04	− 1.2	2	3,605	s.	28	w.	2	18	9	3	3.1		
North Pacific Coast Region.							**56.8**	**− 1.5**											**72**	**0.87**	**− 1.1**										**4.9**		
North Head	211	11	56	29.90	30.13	+ .14	52.4	− 2.6	61	18	56	46	7	49	11	50	48	86		1.28	− 0.5	11	11,881	nw.	52	se.	21	6	13	11	6.2		
North Yakima	1,071	4	.....	.....	.....	.....	63.6	.....	94	19	80	35	10	47	44	.....	.....	.....		0.04	.....	1	.....	nw.	.....	.....	.....	17	11	2	.....	.....	.....
Port Angeles	29	8	53	30.11	30.14	.....	52.2	.....	68	18	60	35	6	44	26	.....	.....	.....		0.72	− 0.6	8	5,220	nw.	28	nw.	2	13	11	6	4.5		
Seattle	125	215	250	29.98	30.11	+ .11	57.5	− 2.6	77	18	66	45	9	49	26	50	44	67		0.35	− 1.4	5	6,072	n.	32	sw.	19	7	15	8	5.7		
Tacoma	213	113	120	29.88	30.10	+ .07	57.8	− 1.6	81	18	67	42	1	49	30	52	47	72		0.63	− 1.5	8	4,115	n.	22	sw.	2	6	13	11	5.9		
Tatoosh Island	86	7	57	30.02	30.12	+ .10	51.8	− 1.2	61	23	56	44	9	47	14	49	47	85		1.49	− 2.7	12	6,294	w.	45	s.	19	8	12	10	5.4		
Medford	1,425	4	.....	.....	.....	.....	62.9	.....	92	4	80	37	1	46	53	.....	.....	.....		T.	.....	0	.....	nw.	.....	.....	.....	17	6	7	.....	.....	.....
Portland, Oreg	153	68	106	29.92	30.08	+ .04	60.6	− 0.7	83	18	71	44	29	50	33	47	45	62		0.91	− 0.9	8	4,472	nw.	18	sw.	9	16	9	5	3.7		
Roseburg	510	9	57	29.53	30.08	+ .05	60.6	− 0.3	87	4	75	39	11	47	44	51	44	63		0.68	− 0.4	5	2,715	n.	17	n.	6	17	13	0	2.7		
Middle Pacific Coast Region.							**61.6**	**− 1.0**											**59**	**0.02**	**− 0.4**										**1.5**		
Eureka	62	73	89	30.03	30.10	+ .05	53.6	− 1.0	66	21	59	42	3	48	22	51	48	86		0.14	− 0.9	1	5,110	nw.	28	sw.	13	11	14	5	4.5		
Mount Tamalpais	2,375	11	18	27.52	29.97	+ .02	61.5	− 2.6	88	4	69	39	12	54	23	49	36	44		T.	− 0.4	0	15,554	nw.	88	nw.	19	28	2	0	0.4		
Point Reyes Light	490	7	18	29.43	29.95	.....	51.7	− 1.1	72	1	56	44	7	48	26	.....	.....	.....		0.01	.....	1	22,755	nw.	68	nw.	10	17	8	5	3.5		
Red Bluff	332	50	56	29.54	29.89	+ .01	74.8	− 0.9	101	4	89	52	16	60	38	56	39	34		0.00	− 0.5	0	4,386	se.	21	nw.	9	29	1	0	0.4		
Sacramento	69	106	117	29.84	29.91	+ .02	69.4	+ 0.5	101	1	85	47	16	54	39	57	47	54		0.00	− 0.2	0	6,364	s.	22	s.	26	30	0	0	0.2		
San Francisco	155	209	213	29.81	29.98	+ .02	57.8	+ 0.8	88	1	65	48	30	51	31	52	48	75		T.	− 0.2	0	10,348	sw.	37	nw.	11	28	2	0	0.9		
San Jose	141	12	110	29.84	29.99	.....	62.2	− 2.8	95	4	77	41	17	47	47	.....	.....	.....		T.	− 0.1	0	4,883	nw.	24	nw.	11	29	1	0	0.6		
South Pacific Coast Region.							**68.1**	**+ 1.4**											**60**	**0.00**	**− 0.1**										**1.2**		
Fresno	327	89	98	29.54	29.88	+ .03	75.6	− 0.2	102	4	92	51	13	59	38	55	37	32		0.00	− 0.1	0	7,568	nw.	27	nw.	15	29	1	0	0.2		
Los Angeles	338	159	191	29.54	29.90	.00	68.7	+ 2.0	96	3	79	53	13	58	31	58	52	65		0.00	− 0.1	0	4,133	sw.	17	s.	11	27	3	0	1.0		
San Diego	87	62	70	29.81	29.90	− .02	66.2	+ 2.4	91	3	72	57	22	60	27	60	57	78		0.00	0.0	0	4,610	nw.	22	nw.	1	24	6	0	2.3		
San Luis Obispo	201	32	40	29.75	29.96	+ .01	62.0	+ 1.6	96	2	76	40	11	48	46	52	46	67		0.00	− 0.1	0	3,587	nw.	20	ne.	19	30	0	0	1.2		
West Indies.																																		
San Juan, P. R	82	8	54	29.92	30.01	.....	80.2	.....	91	1	85	71	12	75	16	.....	.....	.....		8.95	+ 3.1	20	7,341	se.	36	ne.	6	5	12	13	6.4		
Panama Canal.																																		
Balboa Heights	118	7	97	29.69	29.81	− .02	80.6	+ 0.6	90	3	86	72	18	75	16	76	75	86		8.93	+ 1.4	19	4,521	nw.	28	sw.	16	0	12	18	7.7		
Colon	36	30	97	29.78	29.81	− .03	80.7	+ 0.8	92	2	85	71	26	76	14	78	76	87		12.08	− 1.3	24	4,752	n.	24	e.	4	0	5	25	8.7		
Alaska.																																		
Juneau	80	11	49	.....	.....	.....	51.5	.....	38	68	10	58	8	45	28	48	44	78		3.73	.....	18	2,655	s.	17	ne.	10	2	6	22	8.4		

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during June, 1919, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex.	27	5:30 p. m.	6:35 p. m.	0.99	5:43 p. m.	6:05 p. m.	0.03	0.22	0.57	0.78	0.90	0.94	.....	.....	.....	.....	.....	.....	.....	.....	.....
Albany, N. Y.	27	.....	.....	0.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.23	.....	.....	.....
Alpena, Mich.	19	12:20 p. m.	4:10 p. m.	1.88	12:37 p. m.	1:09 p. m.	0.01	0.32	0.75	0.98	1.00	1.05	1.14	1.17	.....	.....	.....	.....	.....	.....	.....
					1:48 p. m.	2:25 p. m.	1.18	0.10	0.20	0.35	0.45	0.54	0.59	0.64	0.68	.....	.....	.....	.....	.....	.....
Amarillo, Tex.	9	7:20 p. m.	D. N. p. m.	1.34	7:34 p. m.	8:10 p. m.	0.08	0.06	0.12	0.19	0.42	0.62	0.69	0.74	0.78	.....	.....	.....	.....	.....	.....
Anniston, Ala.	17	.....	.....	0.60	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.56	.....	.....	.....
Asheville, N. C.	21	.....	.....	0.88	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.63	.....	.....	.....
Atlanta, Ga.	16	9:25 p. m.	11:15 p. m.	1.01	9:37 p. m.	10:12 p. m.	0.03	0.07	0.12	0.22	0.44	0.65	0.78	0.87	.....	.....	.....	.....	.....	.....	.....
Atlantic City, N. J.	27	.....	.....	1.17	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.66	.....	.....	.....
Augusta, Ga.	8	4:35 p. m.	6:15 p. m.	1.93	5:03 p. m.	5:43 p. m.	0.01	0.36	0.76	1.10	1.36	1.52	1.69	1.81	1.88	.....	.....	.....	.....	.....	.....
	26–27	2:50 p. m.	D. N. a. m.	2.11	3:45 p. m.	4:13 p. m.	0.20	0.26	0.60	0.91	1.17	1.39	1.45	.....	.....	.....	.....	.....	.....	.....	.....
Baker, Oreg.	15	.....	.....	T	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(*)	.....	.....	.....
Baltimore, Md.	26	.....	.....	0.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....	.....
Bentonville, Ark.	1	9:20 p. m.	11:25 p. m.	2.15	9:32 p. m.	11:07 p. m.	0.01	0.11	0.39	0.66	0.96	1.12	1.24	1.33	1.41	1.44	1.46	1.50	1.71	2.14	.....
	30	2:25 p. m.	3:10 p. m.	0.88	2:35 p. m.	3:00 p. m.	0.01	0.25	0.54	0.62	0.72	0.83	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5:30 p. m.	6:05 p. m.	0.56	5:30 p. m.	5:50 p. m.	0.00	0.11	0.31	0.41	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Binghamton, N. Y.	17	.....	.....	0.91	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.64	.....	.....	.....
Birmingham, Ala.	18	12:35 a. m.	D. N. a. m.	0.71	12:52 a. m.	1:32 a. m.	0.01	0.08	0.16	0.21	0.32	0.47	0.54	0.62	0.67	.....	.....	.....	.....	.....	.....
Bismarck, N. Dak.	12	.....	.....	0.23	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.22	.....	.....	.....
Block Island, R. I.	27–28	4:35 p. m.	12:10 a. m.	1.76	5:30 p. m.	6:00 p. m.	0.22	0.06	0.18	0.40	0.62	0.71	0.85	.....	.....	.....	.....	.....	.....	.....	.....
Boise, Idaho.	2	.....	.....	T	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T	.....	.....	.....
Boston, Mass.	9	.....	.....	0.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	.....
Buffalo, N. Y.	7	.....	.....	0.27	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.27	.....	.....	.....
Burlington, Vt.	7	.....	.....	0.53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.45	.....	.....	.....
Cairo, Ill.	8	4:36 p. m.	7:25 p. m.	1.25	4:40 p. m.	5:06 p. m.	0.01	0.10	0.30	0.57	0.77	0.89	0.93	.....	.....	.....	.....	.....	.....	.....	.....
Canton, N. Y.	26–27	6:50 a. m.	D. N. a. m.	3.15	5:50 p. m.	7:10 p. m.	0.58	0.11	0.26	0.31	0.35	0.39	0.45	0.45	0.49	0.57	0.68	0.87	1.11	.....	.....
Charles City, Iowa.	9	4:59 p. m.	6:30 p. m.	1.12	5:45 p. m.	6:15 p. m.	0.09	0.05	0.10	0.17	0.37	0.76	1.00	.....	.....	.....	.....	.....	.....	.....	.....
	10	4:45 p. m.	8:30 p. m.	1.31	6:42 p. m.	7:09 p. m.	0.55	0.22	0.33	0.44	0.56	0.69	0.73	.....	.....	.....	.....	.....	.....	.....	.....
	18	4:42 p. m.	5:18 p. m.	0.71	4:51 p. m.	5:06 p. m.	0.01	0.20	0.50	0.66	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Charleston, S. C.	4	D. N. a. m.	6:55 a. m.	2.57	2:07 a. m.	3:12 a. m.	0.08	0.10	0.16	0.22	0.30	0.43	0.55	0.57	0.63	0.66	0.82	1.20	1.40	.....	.....
Charlotte, N. C.	9	3:55 p. m.	6:30 p. m.	0.90	4:51 p. m.	5:21 p. m.	0.12	0.08	0.20	0.41	0.53	0.62	0.70	.....	.....	.....	.....	.....	.....	.....	.....
Chattanooga, Tenn.	11	.....	.....	0.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....	.....
Cheyenne, Wyo.	18	.....	.....	0.19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.17	.....	.....	.....
Chicago, Ill.	14	.....	.....	0.74	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.71	.....	.....	.....
Cincinnati, Ohio.	24	.....	.....	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.32	.....	.....	.....
Cleveland, Ohio.	7	.....	.....	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.40	.....	.....	.....
Columbia, Mo.	3	.....	.....	0.82	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.43	.....	.....	.....
Columbia, S. C.	24	.....	.....	1.47	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.42	.....	.....	.....
Columbus, Ohio.	11	11:05 a. m.	12:35 p. m.	1.05	11:18 a. m.	12:20 p. m.	0.01	0.11	0.29	0.37	0.38	0.40	0.43	0.58	0.71	0.83	0.91	1.00	1.04	.....	.....
Concord, N. H.	27	.....	.....	0.97	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.58	.....	.....	.....
Concordia, Kans.	9	12:25 a. m.	4:00 a. m.	1.08	12:35 a. m.	1:11 a. m.	0.02	0.11	0.21	0.23	0.28	0.37	0.52	0.61	0.63	.....	.....	.....	.....	.....	.....
	28	2:58 p. m.	3:48 p. m.	0.83	3:00 p. m.	3:27 p. m.	0.01	0.22	0.35	0.45	0.56	0.71	0.75	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi, Tex.	18	2:01 p. m.	5:15 p. m.	0.60	2:14 p. m.	2:23 p. m.	0.02	0.20	0.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Dallas, Tex.	20	.....	.....	0.38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....	.....
Davenport, Iowa.	3	3:30 a. m.	5:15 a. m.	0.69	3:36 a. m.	3:46 a. m.	0.01	0.49	0.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Dayton, Ohio.	16	6:10 p. m.	6:50 p. m.	0.87	6:15 p. m.	6:27 p. m.	0.01	0.33	0.76	0.83	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Del Rio, Tex.	22	.....	.....	0.45	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.44	.....	.....	.....
Denver, Colo.	18	.....	.....	0.12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.07	.....	.....	.....
Des Moines, Iowa.	3–4	6:48 p. m.	D. N. a. m.	1.26	7:37 p. m.	8:02 p. m.	0.10	0.17	0.22	0.33	0.49	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....
	18	4:05 p. m.	6:05 p. m.	0.62	5:02 p. m.	5:33 p. m.	0.01	0.15	0.26	0.33	0.39	0.46	0.54	0.58	.....	.....	.....	.....	.....	.....	.....
	20	6:48 p. m.	D. N. p. m.	0.68	6:56 p. m.	7:12 p. m.	0.02	0.09	0.31	0.53	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Detroit, Mich.	13	1:38 p. m.	2:50 p. m.	1.12	1:42 p. m.	2:13 p. m.	0.01	0.17	0.43	0.69	0.81	0.93	1.04	1.09	.....	.....	.....	.....	.....	.....	.....
	20	12:08 p. m.	1:46 p. m.	1.58	1:05 p. m.	1:36 p. m.	0.12	0.06	0.38	0.80	1.15	1.31	1.43	1.45	.....	.....	.....	.....	.....	.....	.....
Devils Lake, N. Dak.	22	.....	.....	0.86	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.44	.....	.....	.....
Dodge City, Kans.	9	.....	.....	0.65	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.39	.....	.....	.....
Drexel, Nebr.	25	10:03 p. m.	11:00 p. m.	0.64	10:17 p. m.	10:37 p. m.	0.02	0.17	0.41	0.51	0.58	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	28	10:20 a. m.	11:45 a. m.	2.15	10:49 a. m.	11:34 a. m.	0.08	0.14	0.47	0.83	1.24	1.47	1.60	1.66	1.94	2.06	.....	.....	.....	.....	.....
Dubuque, Iowa.	1–2	6:15 p. m.	D. N. a. m.	1.72	8:58 p. m.	9:38 p. m.	0.67	0.18	0.29	0.40	0.47	0.49	0.53	0.58	0.66	.....	.....	.....	.....	.....	.....
	23	8:55 p. m.	D. N. p. m.	1.44	9:30 p. m.	10:03 p. m.	0.16	0.16	0.31	0.51	0.74	0.99	1.17	1.22	.....	.....	.....	.....	.....	.....	.....
Duluth, Minn.	1	7:30 p. m.	D. N. p. m.	0.81	8:00 p. m.	8:40 p. m.	0.19	0.11	0.26	0.32	0.37	0.43	0.46	0.51	0.61	.....	.....	.....	.....	.....	.....
Eastport, Me.	27	.....	.....	0.70	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.18	.....	.....	.....
Elkins, W. Va.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Ellendale, N. Dak.	20–21	8:25 p. m.	6:05 a. m.	1.54	12:51 a. m.	1:21 a. m.	0.47	0.05	0.09	0.20	0.36	0.47	0.52	.....	.....	.....	.....	.....	.....	.....	.....
El Paso, Tex.	18	.....	.....	0.20	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.18	.....	.....	.....
Erie, Pa.	25–26	7:08 p. m.	D. N. a. m.	2.28	7:39 p. m.	8:26 p. m.	0.01	0.17	0.28	0.41	0.48	0.65	0.69	0.79	0.91	1.14	1.22	.....	.....	.....	.....
Escanaba, Mich.	15	4:15 p. m.	7:45 p. m.	1.01	4:27 p. m.	4:51 p. m.	0.01	0.11	0.25	0.49	0.66	0.78	.....	.....	.....	.....	.....	.....	.....	.....	.....
	24	D. N. a. m.	7:45 a. m.	1.54	4:52 a. m.	5:37 a. m.	0.05	0.09	0.22	0.34	0.46	0.53	0.56	0.59	0.65	0.77	.....	.....	.....	.....	.....
Eureka, Calif.	12	.....	.....	0.14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.08	.....	.....	.....
Evansville, Ind.	13	11:20 a. m.	3:45 p. m.	0.89	11:56 a. m.	12:36 p. m.	0.05	0.10	0.23	0.32	0.39	0.43	0.51	0.61	0.73	.....	.....	.....	.....	.....	.....
	23–24	9:00 p. m.	D. N. a. m.	1.87	10:12 p. m.	11:08 p. m.	0.19	0.11	0.19	0.29	0.48	0.70	0.85	0.98	1.05	1.20	1.37	1.46	.....	.....	.....
	24–25	10:00 p. m.	D. N. a. m.	1.04	10:05 p. m.	10:23 p. m.	0.01	0.20	0.42	0.57	0.64	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Flagstaff, Ariz.	30	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Fort Smith, Ark.	11	12:32 p. m.	1:08 p. m.	0.54	12:44 p. m.	1:04 p. m.	0.01	0.12	0.27	0.42	0.50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	22	1:31 p. m.	2:14 p. m.	0.60	1:36 p. m.	1:49 p. m.	0.01	0.16	0.43	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fort Wayne, Ind.	7	9:58 a. m.	11:15 a. m.	0.95	10:12 a. m.	10:47 a. m.	0.01	0.08	0.14	0.20	0.46	0.68	0.83	0.88	.....	.....	.....	.....	.....	.....	.....
Fort Worth, Tex.	22	5:19 p. m.	6:21 p. m.	1.11	5:38 p. m.	6:01 p. m.	0.09	0.32	0.50	0.81	0.96	1.01	.....	.....	.....	.....	.....	.....	.....	.....	.....
Fresno, Calif.	‡	.....	.....	‡	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	‡	.....	.....	.....
Galveston, Tex.	29	.....	.....	1.19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.99	.....	.....	.....
Grand Haven, Mich.	2	.....	.....	0.46	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	*	.....	.....	.....
Grand Junction, Colo.	8	.....	.....	0.06	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.06	.....	.....	.....
Grand Rapids, Mich.	11	12:53 p. m.	1:50 p. m.	0.78	12:53 p. m.	1:12 p. m.	0.00	0.08	0.37	0.61	0.73	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Green Bay, Wis.	4	.....	.....	0.13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.13	.....	.....	.....
Greenville, S. C.	12	3:15 p. m.	4:20 p. m.	0.85	3:17 p. m.	3:42 p. m.	0.01	0.22	0.28	0.29	0.53	0.79	.....	.....	.....	.....	.....	.....	.....	.....	.....
	25	6:20 p. m.	7:10 p. m.	0.68	6:37 p. m.	6:54 p. m.	0.02	0.21	0.41	0.59	0.63	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hannibal, Mo.	18	6:27 p. m.	8:36 p. m.	0.64	6:31 p. m.	6:46 p. m.	0.01	0.26	0.47	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Harrisburg, Pa.	15	3:42 p. m.	4:55 p. m.	0.82	3:48 p. m.	4:13 p. m.	0.01	0.16	0.35	0.57	0.73	0.78	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hartford, Conn.	27	.....	.....	0.82	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....	.....
Hatteras, N. C.	26–28	9:50 p. m.	2:50 p. m.	7.68	6:05 a. m.[1]	7:32 a. m.[1]	3.68	0.11	0.22	0.40	0.59	0.67	0.74	1.21	.58	1.89	2.14	2.83	3.37	3.55	.....
Havre, Mont.	10	.....	.....	0.31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.26	.....	.....	.....
Helena, Mont.	11	.....	.....	0.09	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.09	.....	.....	.....
Houghton, Mich.	4	.....	.....	0.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.39	.....	.....	.....
Houston, Tex.	9	10:21 a. m.	3:12 p. m.	1.93	10:56 a. m.	11:31 a. m.	0.05	0.41	0.51	0.55	0.64	0.66	0.71	0.81	.....	.....	.....	.....	.....	.....	.....
	10	7:47 a. m.	1:25 p. m.	1.05	12:17 p. m.	12:35 p. m.	1.06	0.24	0.59	0.71	0.76	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	14–16	8:52 a. m.	11:08 a. m.	8.48	8:17 a. m.	8:56 a. m.	0.06	0.10	0.18	0.23	0.28	0.34	0.48	0.62	0.69	.....	.....	.....	.....	.....	.....
					10:11 a. m.[2]	10:55 a. m.[2]	1.23	0.06	0.20	0.27	0.33	0.42	0.50	0.55	0.64	0.69	.....	.....	.....	.....	.....
Huron, S. Dak.	15	12:45 a. m.	D. N. a. m.	0.62	1:08 a. m.	1:27 a. m.	0.03	0.17	0.30	0.48	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	19	12:02 p. m.	6:20 p. m.	2.05	1:24 p. m.	1:42 p. m.	0.62	0.10	0.24	0.44	0.58	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	26	7:23 a. m.	11:20 a. m.	1.06	8:15 a. m.	8:58 a. m.	0.17	0.06	0.12	0.25	0.36	0.46	0.54	0.69	0.76	0.80	.....	.....	.....	.....	.....
Independence, Calif.	5–6	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....	.....

* Self-register not in use. ‡No precipitation occurred during month. [1] Of 28. [2] Of 15.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during June, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Indianapolis, Ind.	12			1.42														1.22			
Iola, Kans.	13			0.60														0.51			
Jacksonville, Fla.	24	5:24 p. m.	8:45 p. m.	1.09	5:37 p. m.	6:10 p. m.	0.07	0.11	0.22	0.32	0.42	0.55	0.71	0.81							
	27	9:50 a. m.	10:54 a. m.	0.73	9:58 a. m.	10:15 a. m.	0.05	0.15	0.54	0.65	0.68										
	29–30	4:35 p. m.	6:00 p. m.	7.67	6:21 a. m.	6:51 a. m.	2.88	0.08	0.22	0.44	0.73	1.07	1.25								
					7:26 a. m.	7:51 a. m.	4.20	0.09	0.25	0.41	0.52	0.58									
Kalispell, Mont.	14			0.42														0.35			
Kansas City, Mo.	22	3:30 p. m.	6:13 p. m.	0.73	5:17 p. m.	5:47 p. m.	0.11	0.08	0.18	0.28	0.41	0.53	0.60								
Keokuk, Iowa.	3			0.44														0.28			
Key West, Fla.	9	3:58 p. m.	4:35 p. m.	0.54	4:07 p. m.	4:31 p. m.	0.03	0.06	0.11	0.20	0.39	0.51									
	11–12	D. N. p. m.	9:45 a. m.	1.96	7:50 a. m.	8:25 a. m.	0.39							0.97†							
	13	D. N. a. m.	8:20 a. m.	1.82	6:01 a. m.	6:58 a. m.	0.01	0.26	0.54	0.54	0.74	1.12	1.43	1.51	1.54	1.58	1.63	1.80			
		5:15 p. m.	D. N. p. m.	1.10	6:53 p. m.	7:09 p. m.	0.21	0.07	0.29	0.49	0.52										
	18	1:08 p. m.	D. N. p. m.	1.76	1:17 p. m.	1:57 p. m.	0.02	0.41	0.76	1.01	1.16	1.23	1.29	1.34	1.42						
Knoxville, Tenn.	21	4:45 p. m.	5:45 p. m.	1.13	4:47 p. m.	5:22 p. m.	0.01	0.11	0.12	0.16	0.60	0.87	0.97	1.04							
	23	3:25 p. m.	4:35 p. m.	1.38	3:33 p. m.	4:22 p. m.	0.02	0.19	0.54	0.80	1.01	1.07	1.10	1.10	1.12	1.28	1.35				
		5:05 p. m.	9:40 p. m.	0.93	5:08 p. m.	5:33 p. m.	0.01	0.07	0.21	0.42	0.51	0.57									
La Crosse, Wis.	19	4:56 p. m.	7:05 p. m.	1.11	4:59 p. m.	5:20 p. m.	0.01	0.25	0.57	0.81	0.97	1.00									
Lander, Wyo.	3			0.15														0.15			
Lansing, Mich.	19	11:04 a. m.	12:05 p. m.	0.79	11:12 a. m.	11:30 a. m.	0.02	0.26	0.53	0.69	0.73										
Lewiston, Idaho.	13–14			0.12														0.06			
Lexington, Ky.	20	5:11 p. m.	6:40 p. m.	1.43	5:38 p. m.	6:18 p. m.	0.07	0.13	0.17	0.23	0.47	0.80	1.01	1.24	1.32						
	23	8:15 a. m.	3:10 p. m.	1.44	8:25 a. m	8:46 a. m.	0.03	0.15	0.32	0.59	0.76	0.79									
Lincoln, Nebr.	27	5:59 p. m.	8:45 p. m.	0.81	6:01 p. m.	6:19 p. m.	0.01	0.16	0.31	0.45	0.53										
Little Rock, Ark.	23	4:00 p. m.	D. N. p. m.	1.21	5:25 p. m.	5:51 p. m.	0.30	0.06	0.15	0.30	0.44	0.51	0.54								
Los Angeles, Calif.	‡			‡														‡			
Louisville, Ky.	23	3:25 p. m.	7:20 p. m.	0.58	6:13 p. m.	6:38 p. m.	0.06	0.11	0.19	0.30	0.43	0.52									
Ludington, Mich.	24			0.49														0.48			
Lynchburg, Va.	5	8:10 a. m.	5:10 p. m.	1.99	1:45 p. m.	2:11 p. m.	0.95	0.05	0.23	0.36	0.52	0.58	0.61								
	12	1:15 a. m.	7:10 p. m.	1.20	1:30 a. m.	1:54 a. m.	0.01	0.08	0.21	0.36	0.46	0.50									
	26	5:30 a. m.	9:15 a. m.	1.08	6:59 a. m.	7:47 a. m.	0.01	0.09	0.26	0.34	0.46	0.51	0.64	0.70	0.76	0.84	0.88				
Macon, Ga.	26	3:08 p. m.	4:08 p. m.	0.83	3:38 p. m.	4:03 p. m.	0.02	0.26	0.49	0.66	0.74	0.79									
Madison, Wis.	14	12:30 p. m.	1:35 p. m.	0.60	12:30 p. m.	12:55 p. m.	0.00	0.11	0.23	0.34	0.46	0.57									
Marquette, Mich.	10			0.65														*			
Memphis, Tenn.	21	12:01 p. m.	1:25 p. m.	0.90	12:03 p. m.	12:45 p. m.	0.01	0.08	0.20	0.26	0.31	0.39	0.50	0.70	0.86	0.89					
	23	12:33 p. m.	3:15 p. m.	1.12	12:45 p. m.	1:40 p. m.	0.02	0.13	0.27	0.39	0.45	0.49	0.57	0.61	0.68	0.86	0.95	1.06			
	29	4:51 p. m.	6:33 p. m.	1.16	4:56 p. m.	5:07 p. m.	0.01	0.55	1.01	1.08											
Meridian, Miss.	1	8:50 p. m.	D. N. p. m.	1.36	9:45 p. m.	10:13 p. m.	0.16	0.25	0.44	0.67	0.87	0.99	1.04								
	3	D. N. p. m.	D. N. p. m.	1.41	8:19 p. m.	8:50 p. m.	0.01	0.18	0.41	0.69	0.92	1.06	1.16	1.20							
	18–19	D. N. p. m.	D. N. a. m.	0.96	11:51 p. m.	12:15 a. m.	0.02	0.13	0.42	0.65	0.75	0.85									
	21	5:00 p. m.	6:02 p. m.	0.70	5:03 p. m.	5:23 p. m.	0.01	0.24	0.40	0.53	0.59										
	27	5:35 p. m.	D. N. p. m.	1.39	6:23 p. m.	7:07 p. m.	0.04	0.07	0.20	0.37	0.47	0.58	0.68	0.84	0.95	1.09					
Miami, Fla.	2	2:25 p. m.	6:47 p. m.	2.14	3:05 p. m.	3:33 p. m.	0.17	0.23	0.49	0.62	0.83	0.95	1.03								
					5:07 p. m.	5:48 p. m.	1.42	0.10	0.17	0.25	0.27	0.35	0.42	0.50	0.65	0.69					
Milwaukee, Wis.	7			0.34														0.19			
Minneapolis, Minn.	23			1.81														0.79			
Mobile, Ala.	29			0.64														0.64			
Modena, Utah.	3			0.13														0.11			
Montgomery, Ala.	9	D. N. a. m.	D. N. a. m.	0.82	12:32 a. m.	12:55 a. m.	0.01	0.25	0.52	0.64	0.70	0.75									
Moorhead, Minn.	22	7:25 a. m.	8:05 a. m.	0.92	7:33 a. m.	7:46 a. m.	0.01	0.27	0.80	0.90											
Mount Tamalpais, Calif.	13			T.														T.			
Nantucket, Mass.	27–28	5:15 p. m.	10:25 a. m.	1.99	8:44 p. m.	9:01 p. m.	0.43	0.12	0.34	0.54	0.57										
Nashville, Tenn.	4	2:25 p. m.	4:50 p. m.	1.15	3:10 p. m.	3:59 p. m.	0.07	0.10	0.24	0.30	0.58	0.78	0.80	0.81	0.89	0.97	1.03				
	9	12:58 p. m.	1:55 p. m.	0.95	1:02 p. m.	1:32 p. m.	0.02	0.21	0.34	0.53	0.67	0.79	0.87								
New Haven, Conn.	27			1.51														0.55			
New Orleans, La.	13																	0.43			
New York, N. Y.	20			0.77														0.49			
Norfolk, Va.	7	4:20 p. m.	10:20 p. m.	1.58	5:15 p. m.	5:47 p. m.	0.07	0.18	0.42	0.61	0.73	0.82	0.96	1.00							
Northfield, Vt.	14	8:12 a. m.	10:22 a. m.	0.51	9:18 a. m.	9:36 a. m.	T.	0.05	0.15	0.35	0.50										
North Head, Wash.	23			0.09														0.08			
North Platte, Nebr.	8–9	1:50 p. m.	D. N. a. m.	1.54	4:50 p. m.	5:15 p. m.	0.49	0.08	0.22	0.48	0.72	0.81									
Oklahoma, Okla.	9	4:57 p. m.	5:35 p. m.	0.56	5:01 p. m.	5:28 p. m.	0.01	0.05	0.10	0.17	0.23	0.48	0.55								
		7:47 p. m.	9:20 p. m.	0.96	7:51 p. m.	8:13 p. m.	0.01	0.10	0.38	0.67	0.81	0.93									
	21	5:50 p. m.	8:40 p. m.	1.54	5:57 p. m.	6:22 p. m.	0.01	0.38	0.83	1.07	1.36	1.47									
Omaha, Nebr.	31[1]–1	D. N. p. m.	D. N. a. m.	1.04	12:13 a. m.	12:27 a. m.	0.11	0.21	0.52	0.68											
	8	9:13 a. m.	11:10 a. m.	0.69	9:29 a. m.	9:52 a. m.	0.01	0.08	0.25	0.47	0.55	0.60									
Oswego, N. Y.	8	4:26 p. m.	11:00 p. m.	2.38	4:59 p. m.	6:41 p. m.	0.03	0.21	0.38	0.49	0.57	0.68	0.75	0.90	0.99	1.04	1.04	1.13	1.23	1.87	1.95
Palestine, Tex.	10	4:30 a. m.	12:30 p. m.	1.55	4:47 a. m.	5:35 a. m.	0.02	0.22	0.31	0.35	0.38	0.39	0.43	0.46	0.52	0.79	0.84				
Parkersburg, W. Va.	15			0.47														0.45			
Pensacola, Fla.	2	10:18 p. m.	11:30 p. m.	0.84	10:37 p. m.	10:55 p. m.	0.07	0.21	0.43	0.60	0.66										
Peoria, Ill.	20	6:19 p. m.	7:19 p. m.	1.05	6:26 p. m.	6:52 p. m.	0.01	0.09	0.33	0.63	0.85	1.02	1.03								
Philadelphia, Pa.	11			0.39														0.39			
Phoenix, Ariz.	30			T.														T.			
Pierre, S. Dak.	4			1.65														0.36			
Pittsburgh, Pa.	16	7:10 p. m.	D. N. p. m.	1.13	7:36 p. m.	7:54 p. m.	0.11	0.18	0.39	0.67	0.73										
Pocatello, Idaho.	24			T.														T.			
Point Reyes Light, Calif.	12			T.														T.			
Port Angeles, Wash.	13			0.30														0.13			
Port Huron, Mich.	13			0.42														0.42			
Portland, Me.	9			0.79														0.32			
Portland, Oreg.	13			0.36														0.26			
Providence, R. I.	20	4:25 p. m.	7:35 p. m.	2.01	4:36 p. m.	5:16 p. m.	0.02	0.07	0.19	0.39	0.74	1.15	1.48	1.66	1.78						
Pueblo, Colo.	9			0.50														0.50			
Raleigh, N. C.	5			1.19														0.33			
Rapid City, S. Dak.	19	6:10 p. m.	7:12 p. m.	0.88	6:13 p. m.	6:45 p. m.	0.01	0.16	0.35	0.48	0.57	0.62	0.75	0.82							
	28	6:15 p. m.	7:40 p. m.	0.98	6:25 p. m.	6:45 p. m.	0.01	0.16	0.42	0.58	0.69										
Reading, Pa.	6			0.76														0.44			
Red Bluff, Calif.	‡			‡														‡			
Reno, Nev.	11			T.														T.			
Richmond, Va.	10	1:45 p. m.	5:50 p. m.	1.07	2:37 p. m.	3:33 p. m.	0.06	0.12	0.23	0.29	0.34	0.42	0.47	0.51	0.70	0.83	0.92	0.97			
	27	1:10 p. m.	8:15 p. m.	0.80	2:45 p. m.	3:01 p. m.	0.01	0.22	0.39	0.59	0.61										
Rochester, N. Y.	8	1:10 p. m.	2:06 p. m.	0.55	1:38 p. m.	1:50 p. m.	0.03	0.25	0.48	0.51											
	26	1:39 p. m.	4:20 p. m.	1.17	2:14 p. m.	2:56 p. m.	0.04	0.18	0.33	0.39	0.43	0.46	0.55	0.66	0.84	0.94					
Roseburg, Oreg.	10			0.23														0.23			
Roswell, N. Mex.	26–27	11:18 p. m.	4:10 a. m.	1.72	11:32 p. m.	12:22 a. m.	0.01	0.21	0.35	0.42	0.45	0.58	0.76	0.96	1.05	1.10	1.18				
Sacramento, Calif.	‡			‡														‡			

* Self-register not in use. † Stick measurement when excessive rate ceased; register not recording. ‡ No precipitation occurred during month. [1] May 31.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during June, 1919, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Saginaw, Mich	11	3:56 p. m.	6:37 p. m.	1.35	4:10 p. m.	4:35 p. m.	0.03	0.08	0.33	0.62	0.78	1.03	.....	.....	.....	.....	.....	.....	.....	.....
St. Joseph, Mo	10	4:20 p. m.	5:32 p. m.	0.62	5:10 p. m.	5:22 p. m.	0.05	0.30	0.52	0.55	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Louis, Mo	16	3:05 p. m.	4:15 p. m.	0.82	3:16 p. m.	3:33 p. m.	T.	0.21	0.58	0.72	0.75	.....	.....	.....	.....	.....	.....	.....	.....	.....
	17	2:23 p. m.	3:25 p. m.	1.22	2:23 p. m.	2:52 p. m.	.0	0.22	0.51	0.78	1.08	1.12	1.19	.....	.....	.....	.....	.....	.....	.....
	22	11:13 a. m.	11:35 a. m.	0.54	11:19 a. m.	11:29 a. m.	0.01	0.29	0.52	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
St. Paul, Minn	22	.....	.....	0.95	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.54	.....	.....
Salt Lake City, Utah	7	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....
San Antonio, Tex	9	6:24 p. m.	7:15 p. m.	0.64	6:27 p. m.	6:45 p. m.	0.01	0.30	0.46	0.55	0.60	.....	.....	.....	.....	.....	.....	.....	.....	.....
	10	D. N. a. m.	D. N. a. m.	0.58	3:08 a. m.	3:35 a. m.	0.04	0.14	0.25	0.30	0.37	0.46	0.50	.....	.....	.....	.....	.....	.....	.....
	24–25	9:38 p. m.	1:13 a. m.	1.22	10:00 p. m.	10:35 p. m.	0.08	0.08	0.28	0.48	0.64	0.82	0.98	1.05	.....	.....	.....	.....	.....	.....
	26	7:14 a. m.	12:45 p. m.	1.93	8:31 a. m.	9:02 a. m.	0.09	0.07	0.21	0.35	0.58	0.76	0.89	0.91	.....	.....	.....	.....	.....	.....
		3:00 p. m.	8:20 p. m.	1.53	3:04 p. m.	3:53 p. m.	0.01	0.05	0.28	0.50	0.62	0.75	0.95	1.12	1.26	1.34	1.40	.....	.....	.....
San Diego, Calif	‡	.....	.....	‡	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	‡	.....	.....
Sandusky, Ohio	25	.....	.....	0.54	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....
Sandy Hook, N. J	27	.....	.....	1.66	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.52	.....	.....
San Francisco, Calif	13	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....
San Jose, Cal	13	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....
San Luis Obispo, Calif	‡	.....	.....	‡	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	‡	.....	.....
Santa Fe, N. Mex	30	.....	.....	0.71	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.49	.....	.....
Sault Ste. Marie, Mich	7	.....	.....	0.78	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.66	.....	.....
Savannah, Ga	3	7:24 p. m.	1:40 p. m.	1.31	8:43 a. m.	9:10 a. m.	0.28	0.07	0.16	0.34	0.46	0.72	0.80	.....	.....	.....	.....	.....	.....	.....
	5	D. N. a. m.	D. N. a. m.	0.88	3:35 a. m.	4:31 a. m.	0.02	0.08	0.10	0.24	0.37	0.46	0.54	0.55	0.55	0.66	0.76	0.85	.....	.....
Scranton, Pa	14	1:20 p. m.	3:30 p. m.	1.75	2:33 p. m.	3:26 p. m.	0.08	0.07	0.21	0.52	0.86	0.90	0.91	0.94	1.15	1.40	1.59	1.67	.....	.....
	15	2:14 p. m.	3:14 p. m.	0.65	2:32 p. m.	2:44 p. m.	0.02	0.21	0.52	0.58	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Seattle, Wash	13	.....	.....	0.10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.06	.....	.....
Sheridan, Wyo	12	.....	.....	0.34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.31	.....	.....
Shreveport, La	20–21	5:15 p. m.	D. N. a. m.	1.35	8:45 p. m.	9:08 p. m.	0.22	0.35	0.61	0.88	0.99	1.04	.....	.....	.....	.....	.....	.....	.....	.....
	27	4:15 p. m.	5:55 p. m.	1.29	4:25 p. m.	4:53 p. m.	0.04	0.27	0.55	0.76	1.00	1.10	1.17	.....	.....	.....	.....	.....	.....	.....
Sioux City, Iowa	9	4:30 a. m.	9:45 a. m.	2.00	4:43 a. m.	4:57 a. m.	0.05	0.17	0.45	0.66	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	19	4:00 a. m.	5:00 a. m.	0.57	4:09 a. m.	4:29 a. m.	0.01	0.11	0.28	0.40	0.51	.....	.....	.....	.....	.....	.....	.....	.....	.....
Spokane, Wash	13	.....	.....	0.01	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....
Springfield, Ill	3	4:35 p. m.	8:44 p. m.	1.49	6:09 p. m.	6:47 p. m.	0.24	0.14	0.32	0.41	0.48	0.62	0.64	0.72	0.77	.....	.....	.....	.....	.....
Springfield, Mo	21–22	8:30 p. m.	D. N. a. m.	1.23	8:46 p. m.	9:11 p. m.	0.01	0.09	0.24	0.43	0.69	0.88	.....	.....	.....	.....	.....	.....	.....	.....
	26	D. N. a. m.	D. N. a. m.	0.62	1:57 a. m.	2:14 a. m.	0.02	0.14	0.32	0.50	0.56	.....	.....	.....	.....	.....	.....	.....	.....	.....
Syracuse, N. Y	20	5:12 a. m.	5:35 a. m.	0.57	5:14 a. m.	5:19 a. m.	T.	0.56	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Tacoma, Wash	10	.....	.....	0.16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.07	.....	.....
Tampa, Fla	6	5:35 p. m.	7:03 p. m.	0.90	5:52 p. m.	6:11 p. m.	0.01	0.23	0.58	0.84	0.88	.....	.....	.....	.....	.....	.....	.....	.....	.....
	8	3:58 p. m.	6:05 p. m.	2.74	4:07 p. m.	5:26 p. m.	0.02	0.10	0.36	0.59	0.88	1.20	1.54	1.67	1.85	2.03	2.16	2.35	2.62	.....
Tatoosh Island, Wash	21	.....	.....	0.25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.13	.....	.....
Taylor, Tex	16	3:30 p. m.	D. N. p. m.	1.59	4:24 p. m.	5:05 p. m.	0.32	0.07	0.10	0.23	0.36	0.47	0.52	0.67	0.92	0.97	.....	.....	.....	.....
	22	4:55 p. m.	6:40 p. m.	0.67	5:45 p. m.	6:00 p. m.	0.01	0.19	0.51	0.59	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Terre Haute, Ind	24	4:27 p. m.	6:35 p. m.	1.32	4:44 p. m.	5:09 p. m.	0.01	0.20	0.47	0.87	1.15	1.27	.....	.....	.....	.....	.....	.....	.....	.....
Thomasville, Ga	1	2:36 p. m.	3:24 p. m.	0.78	2:38 p. m.	2:58 p. m.	0.01	0.36	0.59	0.68	0.73	.....	.....	.....	.....	.....	.....	.....	.....	.....
	11	12:42 p. m.	2:15 p. m.	0.65	1:46 p. m.	2:03 p. m.	0.05	0.17	0.38	0.53	0.59	.....	.....	.....	.....	.....	.....	.....	.....	.....
Toledo, Ohio	7	1:07 p. m.	2:17 p. m.	0.68	1:39 p. m.	1:55 p. m.	0.08	0.18	0.43	0.53	0.58	.....	.....	.....	.....	.....	.....	.....	.....	.....
	24	6:42 p. m.	7:08 p. m.	0.71	6:43 p. m.	7:05 p. m.	T.	0.27	0.34	0.45	0.63	0.71	.....	.....	.....	.....	.....	.....	.....	.....
Tonopah, Nev	6	.....	.....	T.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	T.	.....	.....
Topeka, Kans	9	5:12 a. m.	5:50 a. m.	0.54	5:21 a. m.	5:33 a. m.	0.01	0.23	0.37	0.41	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	22	7:25 p. m.	8:30 p. m.	0.84	7:31 p. m.	7:55 p. m.	0.01	0.05	0.22	0.51	0.74	0.80	.....	.....	.....	.....	.....	.....	.....	.....
Trenton, N. J	27	.....	.....	0.62	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....
Valentine, Nebr	4	.....	.....	1.40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.38	.....	.....
Vicksburg, Miss	2	3:55 p. m.	D. N. p. m.	2.06	5:29 p. m.	6:08 p. m.	0.23	0.29	0.62	0.84	1.03	1.22	1.39	1.50	1.56	.....	.....	.....	.....	.....
	29	3:10 p. m.	4:45 p. m.	0.81	3:34 p. m.	4:03 p. m.	0.04	0.23	0.36	0.51	0.56	0.66	0.73	.....	.....	.....	.....	.....	.....	.....
Walla Walla, Wash	26	.....	.....	0.02	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.02	.....	.....
Washington, D. C	27	12:20 p. m.	2:05 p. m.	1.46	12:27 p. m.	12:51 p. m.	0.01	0.39	0.87	1.23	1.32	1.37	.....	.....	.....	.....	.....	.....	.....	.....
Wausau, Wis	14	6:55 p. m.	8:46 p. m.	0.79	7:29 p. m.	8:17 p. m.	0.06	0.13	0.26	0.30	0.30	0.30	0.30	0.32	0.42	0.66	0.72	.....	.....	.....
Wichita, Kans	10	.....	.....	0.77	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.37	.....	.....
Williston, N. Dak	11–12	11:40 p. m.	5:07 a. m.	2.08	1:44 a. m.	2:13 a. m.	0.10	0.12	0.43	0.74	0.89	0.94	0.97	.....	.....	.....	.....	.....	.....	.....
					3:25 a. m.	3:41 a. m.	1.11	0.07	0.24	0.85	0.92	.....	.....	.....	.....	.....	.....	.....	.....	.....
Wilmington, N. C	27	D. N. a. m.	6:10 a. m.	1.50	12:21 a. m.	12:51 a. m.	0.05	0.05	0.12	0.19	0.36	0.62	0.73	.....	.....	.....	.....	.....	.....	.....
Winnemucca, Nev	‡	.....	.....	‡	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	‡	.....	.....
Wytheville, Va	9	.....	.....	0.38	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.36	.....	.....
Yankton, S. Dak	9	.....	.....	1.39	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.58	.....	.....
Yellowstone Park, Wyo	7	.....	.....	0.12	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.03	.....	.....

‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, June, 1919.*

Stations.	Altitude above mean sea level, Jan. 1, 1919.	Pressure.			Temperature of the air.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷ 2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.91	30.05	+0.14	47.9	− 3.7	56.9	39.0	70	28	4.08	+0.48	.....
Sydney, C. B. I.	48	30.07	30.11	+0.16	55.2	− 0.2	66.7	43.6	84	34	2.66	−0.57	.....
Halifax, N. S.	88	30.00	30.11	+ .16	57.8	+ 0.1	67.8	47.8	87	34	2.68	−1.08	.....
Yarmouth, N. S.	65	30.03	30.10	+ .15	56.4	+ 1.4	65.1	47.7	78	37	1.75	−1.01	.....
Charlottetown, P. E. I.	38	30.05	30.09	+ .17	57.6	+ 0.2	66.8	48.4	81	36	2.31	−0.36	.....
Chatham, N. B.	28	30.07	30.10	+ .21	61.1	+ 1.1	73.4	48.9	92	38	1.87	−1.59	.....
Father Point, Que.	20	30.04	30.06	+ .19	54.4	+ 1.4	63.5	45.3	76	33	2.84	−0.14	.....
Quebec, Que.	296	29.79	30.11	+ .19	65.8	+ 4.6	76.8	54.8	92	40	2.81	−0.84	.....
Montreal, Que.	187	29.89	30.09	+ .15	68.7	+ 3.8	78.3	59.1	92	43	4.17	+0.64	.....
Stonecliffe, Ont.	489	29.48	30.08	+ .14	62.7	+ 1.1	84.5	40.9	98	26	5.08	+1.92	.....
Ottawa, Ont.	236	29.84	30.10	+ .16	70.9	+ 5.6	82.6	59.2	96	45	2.96	+0.04	.....
Kingston, Ont.	285	29.79	30.10	+ .13	70.0	+ 6.6	78.3	61.7	91	48	3.48	+1.05	.....
Toronto, Ont.	379	29.68	30.07	+ .10	72.4	+ 9.0	83.4	61.3	94	47	2.72	−0.08	.....
Cochrane, Ont.	930	.....	.....	.....	67.6	.....	81.8	53.4	92	31	0.48	.....	.....
White River, Ont.	1,244	28.79	30.07	+ .13	64.6	+ 5.9	79.4	49.9	91	26	1.09	−1.13	.....
Port Stanley, Ont.	592	29.45	30.08	+ .11	70.4	+ 6.6	80.8	60.0	90	44	1.87	−0.86	.....
Southampton, Ont.	656	29.39	.....	.....	69.2	+ 8.8	79.2	59.3	93	42	1.24	−1.11	.....
Parry Sound, Ont.	688	29.43	30.11	+ .15	72.0	+10.3	85.0	59.0	97	42	1.66	−0.76	.....
Port Arthur, Ont.	644	29.40	30.12	+ .18	62.0	+ 5.6	70.8	53.2	87	40	1.18	−1.55	.....
Winnipeg, Man.	760	29.17	29.99	+ .10	67.9	+ 5.7	79.6	56.2	89	35	4.95	+1.66	.....
Minnedosa, Man.	1,690	28.21	29.99	+ .10	64.4	+ 4.8	77.0	51.8	87	28	3.36	+0.36	.....
Le Pas, Man.	860	.....	.....	.....	65.0	.....	77.2	52.8	92	35	3.56	.....	.....
Qu'Appelle, Sask.	2,115	27.72	29.93	+ .06	65.7	+ 5.8	80.0	51.4	94	33	2.95	−0.47	.....
Medicine Hat, Alb.	2,144	27.60	29.81	− .04	69.2	+ 7.2	84.1	54.3	103	33	0.81	−1.95	.....
Moose Jaw, Sask.	1,759	.....	.....	.....	68.1	.....	84.3	51.9	101	25	3.24	.....	.....
Swift Current, Sask.	2,392	27.37	29.94	+ .07	66.5	+ 6.5	82.7	50.4	95	21	0.56	−2.11	.....
Calgary, Alb.	3,428	26.41	29.92	+ .08	59.6	+ 3.6	77.4	41.9	94	27	0.29	−2.16	.....
Banff, Alb.	4,521	25.39	29.90	+ .06	53.4	+ 1.9	68.9	38.0	89	26	1.02	−2.31	0.5
Edmonton, Alb.	2,150	27.60	29.85	+ .01	57.8	+ 0.9	72.2	43.5	89	30	0.87	−1.99	.....
Prince Albert, Sask.	1,450	28.37	29.92	+ .05	64.7	+ 7.0	78.7	50.7	93	30	2.10	−0.41	.....
Battleford, Sask.	1,592	28.17	29.88	+ .02	64.6	+ 5.1	79.9	49.3	97	24	1.32	−1.99	.....
Kamloops, B. C.	1,262	28.75	30.04	+0.17	61.6	− 2.2	74.8	48.4	96	39	0.67	−0.75	.....
Victoria, B. C.	230	29.83	30.09	+ .08	54.4	− 1.9	61.8	47.0	70	43	0.53	−0.67	.....
Barkerville, B. C.	4,180	25.72	30.02	+0.15	46.3	− 4.4	57.5	35.1	77	30	3.78	+0.30	11.2
Triangle Island, B. C.	680	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Prince Rupert, B. C.	170	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Hamilton, Ber.	151	29.98	30.14	+ .02	73.1	− 1.9	78.4	67.8	83	63	2.82	−3.13	.....

SEISMOLOGY.

W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Aug. 2, 1919.]

TABLE 1.—*Noninstrumental earthquake reports, June, 1919.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA.								
	H. m.		° ′	° ′			*Sec.*			
June 21	6 55	Lone Pine	36 37	118 01	3	1	.....	None	.....	G. F. Marsh.
21	19 58	Lone Pine	36 37	118 01	5	1	Several	Loud rumbling.	Furniture moved	G. F. Marsh.
24	21 12	San Diego	32 43	117 10	4	2	1	None	Buildings shaken	H. F. Alciatore.
24	23 24	Lone Pine	36 37	118 01	5	1	25	None	Felt by many	G. F. Marsh.

TABLE 2.—*Instrumental reports, June, 1919.*

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.

Alabama. *Mobile. Spring Hill College.* Earthquake Station. Cyril Ruhlmann, S. J.

Lat., 30° 41′ 44″ N.; long., 88° 08′ 46″ W. Elevation, 60 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

(No earthquake recorded during June, 1919.)

Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 57° 03′ 00″ N.; long., 135° 30′ 06″ W. Elevation, 15.2 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	17.7
	N	10	16.6

(No earthquake recorded during June, 1919.)

Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Wm. H. Cullum.

Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	14
	N	10	18

1919.			H. m. s.	Sec.	μ	μ	Km.	
June 29	.....	P_N....	0 55 41	3	.....	.....	.....	Trace on E.–W.
		L_N....	0 57 50	.....	.....	.....	.....	
		M_N....	0 58 00	8	.....	20	.....	
		C_N....	0 59 45	6	.....	.....	.....	
		F_N....	1 02 ..	.....	.....	.....	.....	
29	.....	eP....	23 26 00	.....	.....	.....	.....	No trace on E.–W. No distinct maximum amplitude about 0.1 mm.
		S_N....	23 30 54	.....	.....	.....	.....	
		e_N....	23 34 30	.....	.....	.....	.....	
		eL_N...	23 39 ..	.....	.....	10	.....	
		F_N....	23 52 ..	.....	.....	.....	.....	

California. *Berkeley. University of California.*

Lat., 37° 52′ 16″ N.; long., 122° 15′ 37″ W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Mount Hamilton. Lick Observatory.*

Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. *Point Loma. Raja Yoga Academy.* F. J. Dick.

Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

1919.			H. m. s.	Sec.	μ	μ	Km.	
June 13	.....	.....	.....	.....	*100	*100	.....	Tremor during 24 hours preceding 15h. 00m.
24	.....	.....	21 11 30	.....	*200	*300	.....	Light shock about 2 sec.
26	.....	.....	.....	.....	*200	*300	.....	Tremors during 24 hours preceding 15h. 00m. on date given.
30	.....	.....	.....	.....	*100	*100	.....	

*Amplitude on instrument.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 124° 57′ 03″ W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstall, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80-kg., astatic, horizontal pendulum.

Instrumental constants .....

1919.			H. m. s.	Sec.	μ	μ	Km.	
June 10	.....	L_N....	7 00 00	.....	.....	.....	.....	Active on both components.
		F_N....	11 30 00	.....	.....	.....	.....	Weaker on E.–W.
14	.....	.....	.....	.....	.....	.....	.....	Visible activity on N.–W. at intervals during the day.
19	.....	L_N....	2 30 00	.....	.....	.....	.....	Visible waves.
		F_N....	4 45 00	.....	.....	.....	.....	

District of Columbia. *Washington. U. S. Weather Bureau.*

Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.

Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.

Instrumental constants..	V	T_0
	110	6.4

1919.			H. m. s.	Sec.	μ	μ	km.	
June 15	.....	eE....	10 23 ..	.....	.....	.....	.....	Very feeble quake.
		F.....	10 30 ..	.....	.....	.....	.....	
29	.....	P.....	23 20 06	.....	.....	.....	3,000	
		S.....	23 24 48	.....	.....	.....	.....	
		L.....	23 27 26	.....	.....	.....	.....	
		L.....	23 29 30	24	.....	.....	.....	
30	.....	F.....	0 10 ..	.....	.....	.....	.....	

District of Columbia. *Washington. Georgetown University.* F. A. Tondorf, S. J.

Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: Decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants...		V	T_0	ε
	E	165	5.4	0
	N	143	5.2	0
	Z	80	3.0	0

1919.			H. m. s.	Sec.	μ	μ	km.	
June 29	.....	e.....	15 17 29	.....	.....	.....	.....	Heavy microseisms.
		iE?...	15 21 46	.....	.....	.....	.....	Doubtful seismic origin.
		iN....	15 21 48	.....	.....	.....	.....	
		F.....	16 ca	.....	.....	.....	.....	
29	.....	eP....	23 20 08	.....	.....	.....	.....	Heavy microseisms.
		iS.....	23 24 48	.....	.....	.....	.....	
		eL?...	23 26 30	11	.....	.....	.....	On Bosch photographic machine, $23^h\ 27^m\ 36^s$.
		ME1...	23 27 07	11	*1,700	.....	.....	
		ME2...	23 30 41	16	*1,400	.....	.....	
		F?....	1 +	.....	.....	.....	.....	Very doubtful.
			Vertical.			*Az.*		
29	.....	*eP....	*23 20 08*	.....	.....	.....	.....	Heavy microseisms.
		*eS.....	*23 24 49*	.....	.....	.....	.....	
		*eL.....	*23 26 24*	*11*	.....	.....	.....	
		*M.....	*23 33 15*	*16*	*300	.....	.....	
		*F.....	*1 +*	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental reports, June, 1919*—Continued.

Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant..T_0 18.4. Sensitiveness 0.40 arc tilt=1 mm.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.
			H. m. s.	*Sec.*	*μ*	*μ*	*km.*	
June 1	.....	L.....	7 10 30	.....	.....	.....	.....	
		M.....	7 11 48	15	*300	.....	.....	
		C.....	7 16 ..	19	.....	.....	.....	
		F.....	7 41 ..	18	.....	.....	.....	
10	.....	eP.....	20 30 36	.....	.....	.....	.....	
		L.....	20 37 ..	.....	.....	.....	.....	
		M.....	20 44 00	19	*300	.....	.....	
		C.....	20 50 ..	20	.....	.....	.....	
		F.....	20 59 ..	.....	.....	.....	.....	
15	.....	L.....	19 43 ..	.....	.....	.....	.....	
		M.....	19 45 18	18	*100	.....	.....	
		F.....	19 48 ..	.....	.....	.....	.....	
24	.....	L.....	19 16 ..	.....	.....	.....	.....	
		M.....	19 26 ..	18	*100	.....	.....	
		F.....	19 35 ..	.....	.....	.....	.....	
26	.....	L.....	2 10 30	.....	.....	.....	.....	
		M.....	2 11 54	.....	*100	.....	.....	
		F.....	2 13 ..	.....	.....	.....	.....	
28	.....	eP.....	5 13 ..	.....	.....	.....	.....	Paper slipping.
		L.....	5 25 48	.....	.....	.....	.....	
		M.....	5 29 06	18	*200	.....	.....	
		C.....	5 33 ..	.....	.....	.....	.....	
		F.....	5 54 ..	.....	.....	.....	.....	
29	.....	P.....	23 25 18	18	.....	.....	.....	
		eS.....	23 34 42	.....	.....	.....	.....	
		eL.....	23 45 24	.....	.....	.....	.....	
		M.....	23 49 18	17	*600	.....	.....	
		M.....	23 51 54	.....	.....	.....	.....	
		C.....	24 02 ..	20	.....	.....	.....	
		F.....	25 12 ..	19	.....	.....	.....	
30	.....	eP.....	8 43 ..	.....	.....	.....	.....	Difficult to identify because of tremors.
		eL.....	9 08 30	.....	.....	.....	.....	
		M.....	9 15 00	20	*200	.....	.....	
		C.....	9 19 18	20	.....	.....	.....	
		F.....	9 51 ..	18	.....	.....	.....	

* Trace amplitude.

Illinois. *Chicago. University of Chicago.* U. S. Weather Bureau.

Lat., 41° 47′ N., long., 87° 37′ W. Elevation, 180.1 meters.

Instruments: Two Milne-Shaw horizontal pendulums, 0.45 kg.

Instrumental constants..		*V*	T_0	ε	Sensitivity.
	E	150	12	20:1	1″ arc tilt=26.6 mm.
	N	150	8	20:1	1″ arc tilt=13.2 mm.

1919.			*H. m. s.*	*Sec.*	*μ*	*μ*	*km.*	
June 1	.....	iP.....	7 15 45	.....	.....	.....	.....	Record difficult to read.
		S?.....	7 24 37	.....	.....	.....	.....	
		L?.....	7 34 ..	.....	.....	.....	.....	
		F.....	8 15 ..	.....	.....	.....	.....	
4	.....	eE.....	9 46 ..	.....	.....	.....	.....	Not discernible on N.–S.
		eL.....	9 51 30	.....	.....	.....	.....	
		L.....	9 57 ..	15	.....	.....	.....	
		F.....	10 30 ..	.....	.....	.....	.....	
9	.....	eL.....	7 55 ..	.....	.....	.....	.....	May not be seismic.
		F.....	8 20 ..	.....	.....	.....	.....	
12	.....	eL.....	11 49 ..	.....	.....	.....	.....	Time correction uncertain.
		L.....	11 52 ..	18	.....	.....	.....	
		F.....	12 13 ..	.....	.....	.....	.....	
15	.....	e.....	10 16 30	.....	.....	.....	.....	Very feeble. Time correction uncertain.
		L.....	10 31 ..	.....	.....	.....	.....	
		F.....	10 45 ..	.....	.....	.....	.....	
29	.....	P.....	0 51 00	.....	.....	.....	3,000	
		S.....	0 55 43	.....	.....	.....	.....	
		L.....	1 01 38	.....	.....	.....	.....	
		F.....	1 30 ..	.....	.....	.....	.....	
29	.....	P.....	15 26 04	.....	.....	.....	2,920	
		S.....	15 30 41	.....	.....	.....	.....	
		L.....	15 38 20	24	.....	.....	.....	
		L.....	15 46 00	.....	.....	.....	.....	
		F.....	16 15 ..	.....	.....	.....	.....	
29	.....	P.....	23 20 15	.....	.....	.....	2,960	
		S.....	23 24 55	.....	.....	.....	.....	
		L?.....	23 27 20	.....	.....	.....	.....	
		L.....	23 30 00	30	.....	.....	.....	
		L.....	23 40 00	16	.....	.....	.....	
30	.....	F.....	1 30 ..	.....	.....	.....	.....	
30	.....	P.....	7 50 43	.....	.....	.....	2,890	
		S.....	7 55 18	.....	.....	.....	.....	
		eL.....	7 59 10	.....	.....	.....	.....	
		L.....	8 23 00	22	.....	.....	.....	
		L.....	8 32 00	16	.....	.....	.....	
		F.....	10 20 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, June, 1919*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.

Kansas. *Lawrence. University of Kansas.* Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants..		V	T_0	ε
	E	177	3.4	4:1
	N	205	3.4	4:1

(Report for June, 1919, not received.)

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants..		V	T_0
	E	10	15
	N	10	15

1919			H. m. s.	Sec.	μ	μ	km.	
June 29	.....	P.....	23 20 14	3	.....	.....	2,970	
		IS_N...	23 24 55	14	.....	.....	.....	
		S_E.....	23 24 54	12	.....	.....	.....	
		eL_N...	23 29 20	22	.....	.....	.....	
		eL_E...	23 31 20	.....	.....	.....	.....	L difficult to determine.
		M_E....	23 30 47	14	280	.....	.....	
		M_N....	23 33 46	16	.....	260	.....	
		C_N....	23 35 ..	13	.....	.....	.....	
		C_N....	23 44 ..	10	.....	.....	.....	
30	.....	F_N....	0 17 ..	10	.....	.....	.....	
		F_E....	0 18 ..	10	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants..		V	T_0	ε
	E	80	23	0
	N	50	25	4:1

(Report for June, 1919, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants..	V	T_0	ε
	80	7	5:1

(Report for June, 1919, not received.)

New York. Ithaca. Cornell University. Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration.

Instrumental constants..		V	T_0	ε
	E	13	22	4:1
	N	14	25	4:1

(Report for June, 1919, not received.)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.

New York. *New York. Fordham University.* D. H. Sullivan, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants..		V	T_0	ε
	E	72	5.0	0
	N	72	5.0	0

(Report for June, 1919, not received.)

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 25 kg.

Instrumental constants..	V	T_0
	10	20

1919			H. m. s.	Sec.	μ	μ	Km.	
June 29	.....	P_E....	23 17 14	.....	.....	.....	970	
		P_N....	23 17 20	.....	.....	.....	.....	
		S_N....	23 18 56	.....	.....	.....	.....	
		S_E....	23 19 ..	.....	.....	.....	.....	
		L_E....	23 20 12	.....	.....	.....	.....	
		L_N....	23 20 20	.....	.....	.....	.....	
		M_N....	.....	.....	.....	*6,500	.....	
		M_E....	23 21 56	.....	.....	*5,500	.....	
		F_E....	23 25 16	.....	.....	.....	.....	
		F_N....	23 45 ..	.....	.....	.....	.....	

*Trace amplitude.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. W. M. Hill.

Lat., 18° 09′ N.; long., 65° 27′ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants..		V	T_0
	E	10	17
	N	10	19

1919			H. m. s.	Sec.	μ	μ	Km.	
June 28	.....	P_N....	1 45 39	2	.....	.....	.....	Local; felt at Humacao, P. R.
		P_E....	1 45 40	2	.....	.....	.....	
		M_E....	1 46 10	.....	80	.....	.....	
		M_N....	1 46 14	.....	.....	120	.....	
		F.....	1 51 ..	3	.....	.....	.....	
29	.....	eP_E...	23 19 12	4	.....	.....	.....	
		eP_N...	23 19 27	.....	.....	.....	.....	
		PR_E...	23 19 35	.....	.....	.....	.....	
		PR_N...	23 19 52	.....	.....	.....	.....	
		S_E.....	23 23 11	12	.....	.....	.....	
		S_N.....	23 23 43	.....	.....	.....	.....	
		eL_E...	23 25 26	.....	.....	.....	.....	
		eL_N...	23 27 07	.....	.....	.....	.....	
		M_E....	23 29 40	17	160	.....	.....	
		M_N....	23 30 01	19	.....	320	.....	
		C_N....	23 31 ..	14	.....	.....	.....	
		C_E....	23 34 ..	18	.....	.....	.....	
		F_N....	23 44 ..	13	.....	.....	.....	
		F_E....	23 50 ..	13	.....	.....	.....	

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants..		V	T_0
	E	10	15
	N	10	16

1919			H. m. s.	Sec.	μ	μ	Km.	
June 29	.....	P.....	23 21 00	.....	.....	.....	3,540	
		S.....	23 26 20	.....	.....	.....	.....	
		L.....	23 29 16	.....	.....	.....	.....	
		L.....	23 34 ..	20	.....	.....	.....	
		F.....	24 00 ..	.....	.....	.....	.....	

TABLE 2.—*Instrumental reports, June, 1919*—Continued.

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80k. vertical seismograph.

Instrumental constants..V 120 T_0 26

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
June 29	.....	i.....	0 57 54	.....	.....	.....	.....	Very small amplitudes.
		e.....	1 07 18	.....	.....	.....	.....	Small microseisms prevent the reading of P.
			1 20 ..	7.5	.....	.....	.....	
		F.....	1 40 ..	.....	.....	.....	.....	
29	.....	*O*.....	*15 06 05*	.....	.....	.....	6,600	Italian quake reported in press.
		P_N.....	15 16 10	.....	.....	.....	.....	
		ePR_{IN}	15 18 40	.....	.....	.....	.....	
		eS_N.....	15 24 18	.....	.....	.....	.....	
		eL.....	15 34 30	22	.....	.....	.....	
		F.....	15 50 ..	.....	.....	.....	.....	
29	.....	*O*.....	*23 14 14*	.....	.....	.....	3,590	Very sharp offsets mark P. and S. eL is difficult to determine.
		iP.....	23 21 01	.....	.....	.....	.....	
		iS.....	23 26 24	.....	.....	.....	.....	
		L.....	23 31 30	.....	.....	.....	.....	Amplitudes small.
		L.....	23 35 ..	20	.....	.....	.....	
		L.....	23 46 ..	12	.....	.....	.....	
30	.....	L.....	0 15 ..	12	.....	.....	.....	
		F.....	0 35 ..	.....	.....	.....	.....	
30	.....	eN?...	7 48 30	.....	.....	.....	.....	Very small amplitudes.
		e.....	7 51 18	.....	.....	.....	.....	L waves regular and sinusodial throughout.
		eL.....	8 15 ..	20	.....	.....	.....	
			9 00 ..	15	.....	.....	.....	
		F.....	9 05 ..	.....	.....	.....	.....	

Canada. *Toronto. Dominion Meteorological Service.*

Lat,. 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant..T_0 18. Pillar deviation, 1 mm. swing of boom=0.45″.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.
June 2	.....	L.....	6 59 18	.....	.....	.....	.....	Doubtful as to being seismic.
		M.....	6 59 48	.....	*200	.....	.....	
		F.....	7 03 06	.....	.....	.....	.....	
10	.....	L.....	20 57 54	.....	.....	.....	.....	
		M.....	20 58 36	.....	*100	.....	.....	
		F.....	21 03 48	.....	.....	.....	.....	
15	.....	M?....	16 17 54	.....	*100	.....	.....	Small micros going on.
15	.....	M.....	18 05 36	.....	*100	.....	.....	Do.
29	.....	L.....	1 03 18	.....	.....	.....	.....	
		L.....	1 12 00	.....	*100	.....	.....	Small micros of uniform character and intervals going on from 0^h 30^m 30^s to 1^h 30^m 42^s.
29	.....	L.....	15 39 48	.....	.....	.....	.....	
		L.....	15 42 30	.....	.....	.....	.....	
		M.....	15 43 36	.....	*100	.....	.....	
		F.....	15 50 12	.....	.....	.....	.....	
29	.....	P?....	23 21 54	.....	.....	.....	2,830?	Marked disturbance.
		S.....	23 26 24	.....	.....	.....	.....	
		iS.....	23 29 42	.....	.....	.....	.....	
		i.....	23 30 24	.....	.....	.....	.....	
		L.....	23 32 12	.....	.....	.....	.....	
		M.....	23 33 24	.....	*2,100	.....	.....	
		iL.....	23 34 54	.....	.....	.....	.....	
30	.....	F.....	0 30 24	.....	.....	.....	.....	
30	.....	eL.....	8 22 30	.....	.....	.....	.....	
		eL.....	8 32 48	.....	.....	.....	.....	
		M.....	8 45 12	.....	*200	.....	.....	
		F.....	9 10 12	.....	.....	.....	.....	

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instruments: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant..T_0 18. Pillar deviation, 1 mm. swing of boom=0.54″.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.
June 2	.....	P.....	7 13 13	.....	.....	.....	.....	May not be a quake.
		M.....	7 14 02	.....	*100	.....	.....	
10	.....	L?....	21 03 00	.....	.....	.....	.....	
		M.....	21 09 24	.....	*100	.....	.....	
		F.....	21 14 29	.....	.....	.....	.....	
11	.....	M?....	6 55 09	.....	*50	.....	.....	May not be a quake.
14	.....	M.....	8 01 32	.....	*100	.....	.....	
15	.....	L?....	16 25 24	.....	.....	.....	.....	
		M.....	16 27 23	.....	*200	.....	.....	
		F.....	16 30 51	.....	.....	.....	.....	
15	.....	P?....	17 44 14	.....	.....	.....	.....	
		M.....	17 46 13	.....	*300	.....	.....	
		F.....	17 50 11	.....	.....	.....	.....	
29	.....	P or L.	1 06 00	.....	.....	.....	.....	
		M.....	1 06 59	.....	*500	.....	.....	
		F.....	1 12 53	.....	.....	.....	.....	
29	.....	M.....	15 51 48	.....	*200	.....	.....	
29	.....	P?....	23 22 19	.....	.....	.....	.....	
		S?....	23 28 42	.....	.....	.....	.....	
		L.....	23 38 03	.....	.....	.....	.....	
		M.....	23 48 12	.....	*1,800	.....	.....	
30	.....	F.....	00 46 14	.....	.....	.....	.....	
30	.....	M.....	8 44 00	.....	*200	.....	.....	
		F.....	9 19 44	.....	.....	.....	.....	

* Trace amplitude.

SEISMOLOGICAL DISPATCHES.[1]

Seattle, Wash., June 5, 1919.

What seemingly was an earth disturbance gave buildings in Seattle a slight shaking up to-night. The disturbance was felt as far as 45 miles from here. (Associated Press.)

Florence, Italy, June 29, 1919.

A violent earthquake shock was felt here this afternoon at 5:30 o'clock and reports state that neighboring towns were also shaken. So far as known only slight damage was done. (Associated Press.)

Florence, Italy, June 29, 1919.

Additional advice shows that damage was done by the earthquake of to-day. The tremor was sharp, people rushing from houses in panic. The damage in this city was slight.

Rome, Italy, June 30, 1919.

One hundred and twenty persons are estimated to have been killed in and near Vicchio, the center of the earth movements Sunday, in the Florence district, according to the Tempo. The town of Vicchio was reduced to a heap of ruins and a number of the villages were destroyed. (Associated Press.)

[1] Reported by the organization indicated and collected by the seismological station at Georgetown University, Washington, D. C.

TABLE 3.—*Late reports (instrumental).*

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long., 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants.. V 120 T_0 26

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	*km.*	
Apr. 27	.....	$e?_N$	0 52 07	.....	.....	.....	.....	Amplitudes very small.
		eL?	1 26 ..	28	.....	.....	.....	Preliminary waves very irregular.
		L	1 32 ..	24	.....	.....	.....	
		L	1 45 ..	15	.....	.....	.....	
		F	2 ca ..	.....	.....	.....	.....	
28	.....	e_E	6 53 52	.....	.....	.....	.....	
		e_N	6 58 08	.....	.....	.....	.....	
		eL_E	7 02 ..	20	.....	.....	.....	
		L	7 12 ..	12	.....	.....	.....	
		L	7 30 ..	12	.....	.....	.....	
		L	7 40 ..	12	.....	.....	.....	
		F	8	.....	.....	.....	.....	
30	.....	*O*	*7 16 30*	.....	.....	.....	(1)	
		eP	7 31 30	.....	.....	.....	.....	All phases difficult to read with precision, but all are readily determined as to character.
		ePR_1	7 36 18	.....	.....	.....	.....	
		eS?	7 44 12	.....	.....	.....	.....	
		eL	8 01 ..	55	.....	.....	.....	
		L	8 20 ..	25	.....	.....	.....	
		L	8 35 ..	18	.....	.....	.....	
		L	8 50 ..	15	.....	.....	.....	
		L	9 10 ..	14	.....	.....	.....	
		LR_1	9 20 ..	18	.....	.....	.....	
		L	9 35 ..	20	.....	.....	.....	
		L	10 00 ..	16	.....	.....	.....	
		L	10 20 ..	18	.....	.....	.....	
		L	10 35 ..	16	.....	.....	.....	
		L	11 05 ..	16	.....	.....	.....	
		L	11 30 ..	16	.....	.....	.....	
		L	12 00 ..	16	.....	.....	.....	
		F	12 30 ..	.....	.....	.....	.....	
May 1	.....	eL_N	5 59 ..	25	.....	.....	.....	
		L	6 10 ..	20	.....	.....	.....	
		L	6 22 ..	15	.....	.....	.....	
		F	6 40 ..	.....	.....	.....	.....	
2	.....	e	2 32 ..	.....	.....	.....	.....	
		e	2 34 ..	.....	.....	.....	.....	
		$eL?_E$	2 41 48	.....	.....	.....	.....	
		L_N	2 52 ..	25	.....	.....	.....	
		L_N	2 57 ..	21	.....	.....	.....	
		L	3 05 ..	21	.....	.....	.....	
		L	3 12 ..	17	.....	.....	.....	
		L	3 24 ..	16	.....	.....	.....	
		L	3 40 ..	16	.....	.....	.....	
		L	3 51 ..	16	.....	.....	.....	
		L	4 20 ..	15	.....	.....	.....	
		F	4 40 ..	.....	.....	.....	.....	
3	.....	e	6 15 24 6 22 ..	7	.....	.....	.....	May not be seismic.
3	.....	*O*	*0 53 10*	.....	.....	.....	9,460	
		iP	1 04 46	.....	.....	.....	.....	
		iS	1 15 20	.....	.....	.....	.....	
		$L?_E$	1 30 30	.....	.....	.....	.....	
		L	1 34 ..	34	.....	.....	.....	
		L	1 45 ..	20	.....	.....	.....	
		L	2 00 ..	18	.....	.....	.....	
		L	2 10 ..	16	.....	.....	.....	
		L	2 25 ..	13	.....	.....	.....	
		L	2 40 ..	11	.....	.....	.....	
		L	3 00 ..	11	.....	.....	.....	
		L	3 19 ..	12	.....	.....	.....	
		L	3 40 ..	9	.....	.....	.....	
		L	4 08 ..	10	.....	.....	.....	
		F	4 15 ..	.....	.....	.....	.....	

[1] 12600 ca.

Canada. *Ottawa. Dominion Astronomical Observatory*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E.	Amplitude. A_N.	Distance.	Remarks.
1919			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 6	.....	*O*	*19 48 19*	.....	.....	.....	9,700	
		eP	20 01 06	.....	.....	.....	.....	
		S	20 11 51	.....	.....	.....	.....	
		L	20 31 ..	50	.....	.....	.....	
		L	20 45 ..	22	.....	.....	.....	
		L	20 55 ..	18	.....	.....	.....	
		L	21 05 ..	17	.....	.....	.....	
		L	21 15 ..	17	.....	.....	.....	
		L	21 30 ..	15	.....	.....	.....	
		L	21 44 ..	18	.....	.....	.....	
		L	22 05 ..	18	.....	.....	.....	
		L	22 30 ..	15	.....	.....	.....	
		L	22 50 ..	12	.....	.....	.....	
		F	23 05 ..	.....	.....	.....	.....	
7	.....	*O*	*5 21 58*	.....	.....	.....	9,020	
		eP	5 34 12	.....	.....	.....	.....	
		eS?	5 44 24	.....	.....	.....	.....	
		eSR1?	5 51 00	.....	.....	.....	.....	
		eL	6 04 ..	40	.....	.....	.....	
		L	6 22 ..	18	.....	.....	.....	
		L	6 30 ..	17	.....	.....	.....	
		L	6 50 ..	15	.....	.....	.....	
		F	7 15 ..	.....	.....	.....	.....	
8	.....	eL_E	11 05 .. 11 15 ..	18	.....	.....	.....	N.-S. lost in microseisms.
8	.....	L	21 20 .. 21 32 ..	.....	.....	.....	.....	Rather irregular. May not be seismic.
20	.....	*O*	*4 19 54*	.....	.....	.....	3,980	
		P_E	4 27 11	.....	.....	.....	.....	
		S	4 32 57	.....	.....	.....	.....	
		L_N	4 37 30	.....	.....	.....	.....	
		L	4 40 ..	15	.....	.....	.....	
		L	4 46 ..	7	.....	.....	.....	
		F	5 05 ..	.....	.....	.....	.....	
22	.....	*O*	*11 53 48*	.....	.....	.....	6,760	
		P	12 03 02	.....	.....	.....	.....	
		S	12 11 19	.....	.....	.....	.....	
		eL	12 22 ..	.....	.....	.....	.....	
		L	12 26 ..	20	.....	.....	.....	
		L	12 30 ..	18	.....	.....	.....	
		L	12 42 ..	13	.....	.....	.....	
		L	12 50 ..	12	.....	.....	.....	
		F	.....	.....	.....	.....	.....	Lost in changing the sheets at $13^h\ 15^m$.
23	.....	i	3 16 03	.....	.....	.....	.....	
		i	3 24 42	.....	.....	.....	.....	
		eL_E	3 32 ..	22	.....	.....	.....	Very irregular periods on N.-S. Amplitudes very small throughout.
		L	3 45 ..	22	.....	.....	.....	
		F	4 05 ..	.....	.....	.....	.....	
29	.....	eL	11 55 .. 12 20 ..	.....	.....	.....	.....	Very faint: barely discernible.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North; in the meridian.

Instrumental constant..18. T_0 Pillar deviation, 1 mm. swing of boom=0.50″.

1919.			*H. m. s.*	*Sec.*	μ	μ	*km.*	
May 23	.....	L	3 33 36	.....	.....	.....	.....	
		M	3 40 12	.....	*100	.....	.....	
		F	4 05 00	.....	.....	.....	.....	

*Trace amplitude.

Chart I. Hydrographs of Several Principal Rivers, June, 1919.

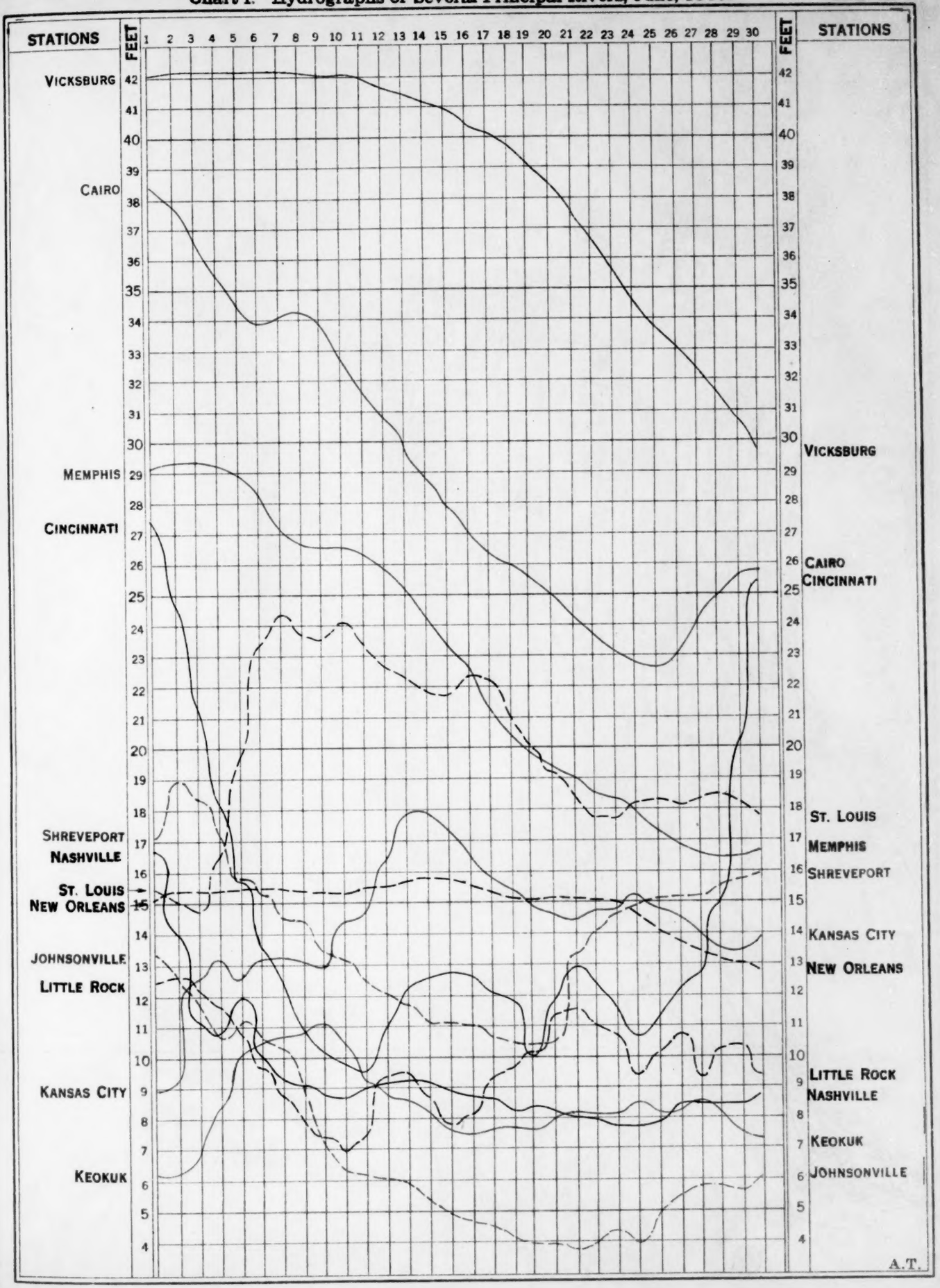


Chart II. Tracks of Centers of High Areas, June, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

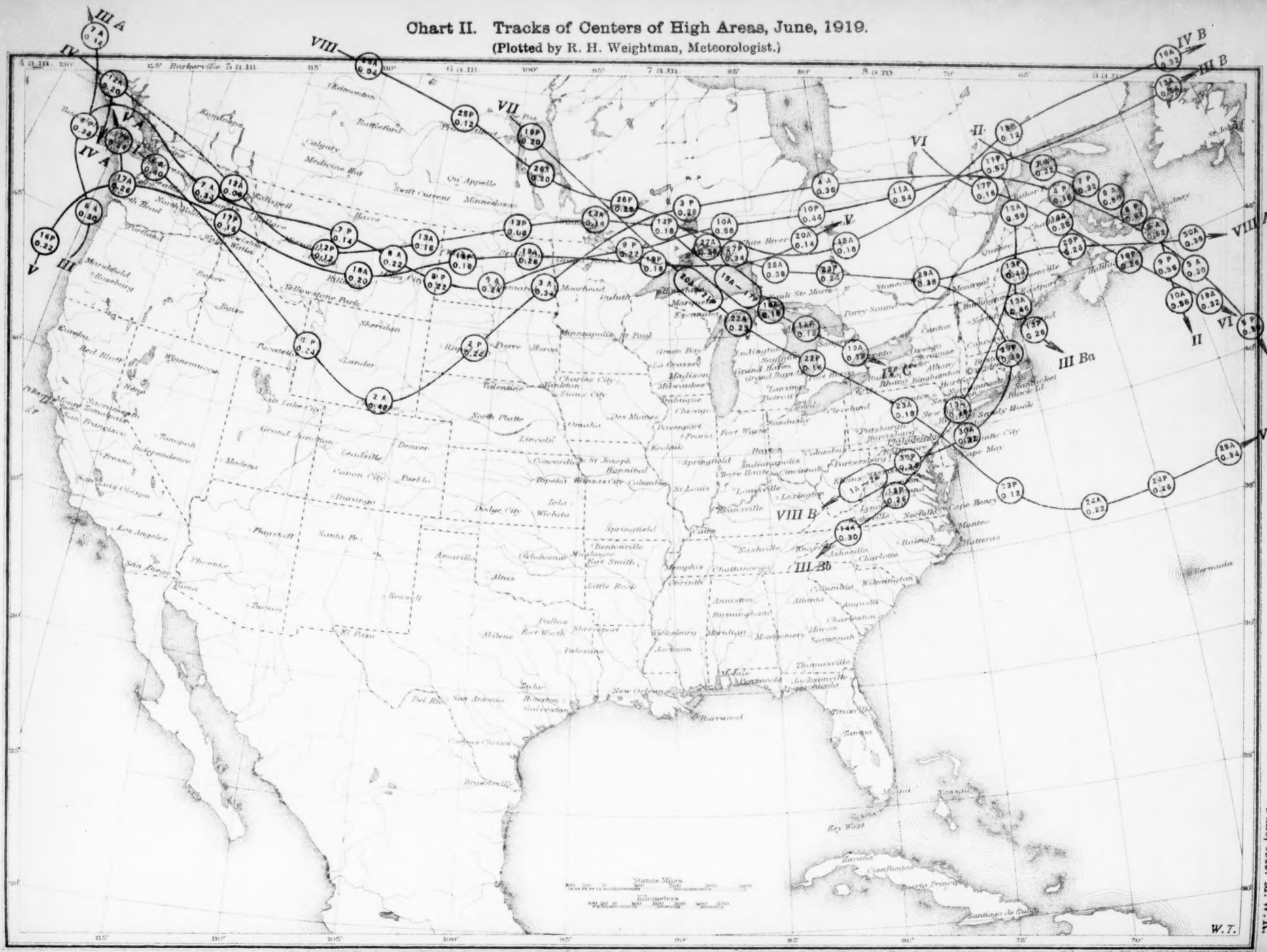
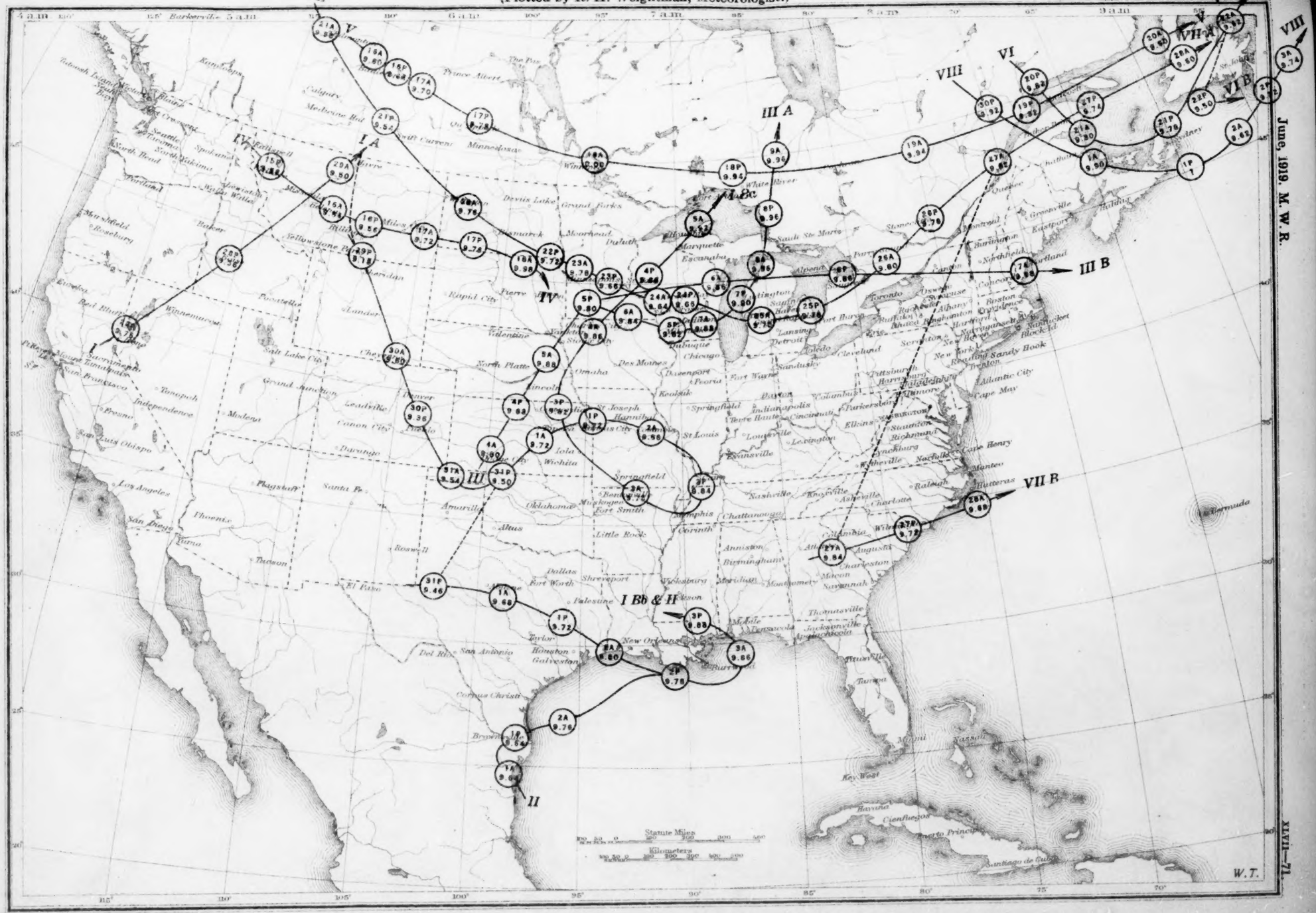


Chart III. Tracks of Centers of Low Areas, June, 1919.

(Plotted by R. H. Weightman, Meteorologist.)

Chart III. Tracks of Centers of Low Areas, June, 1919.

(Plotted by R. H. Weightman, Meteorologist.)



June, 1919. M. W. R.

XLVIII—71.

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, June, 1919.

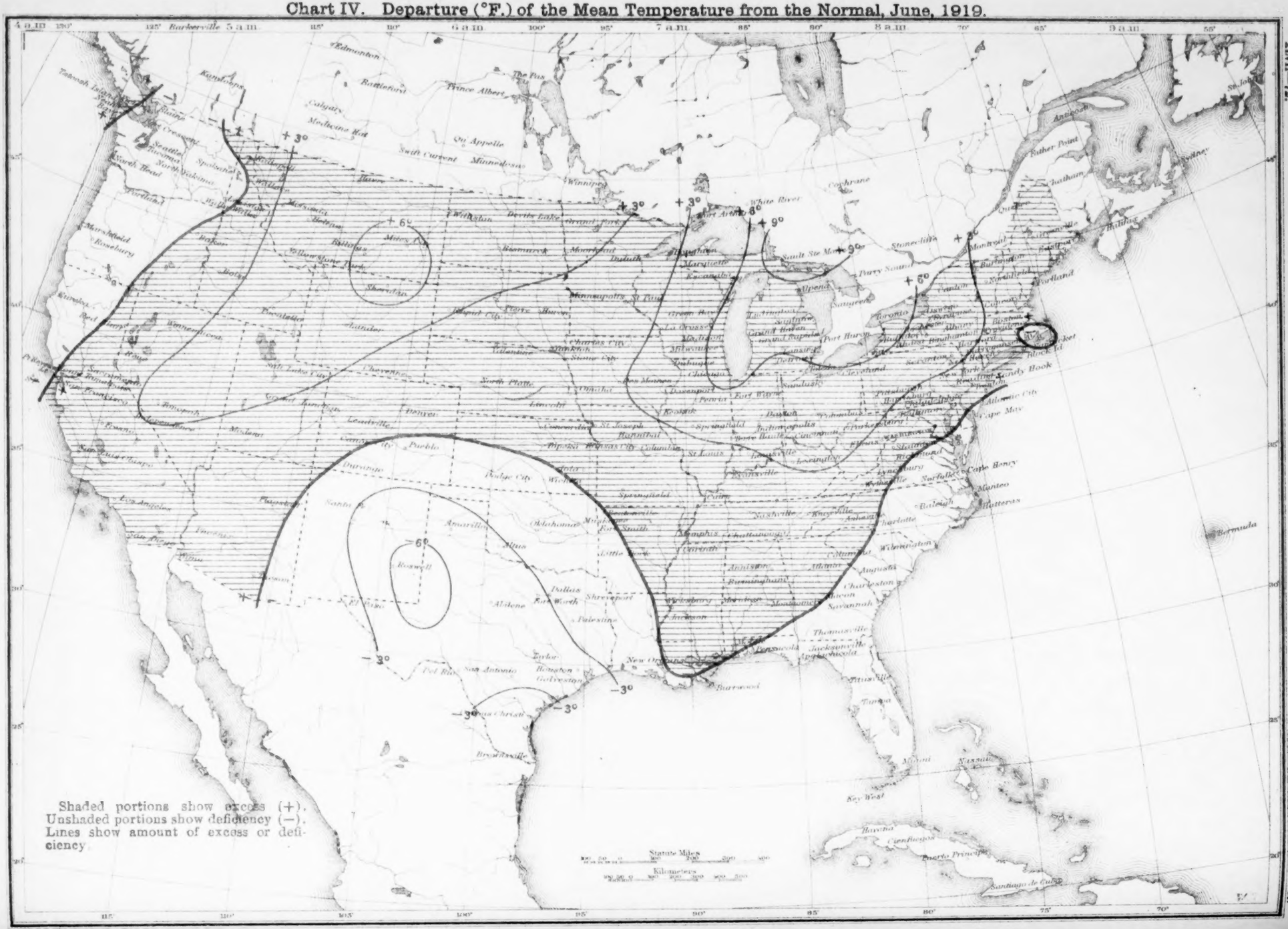

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart V. Total Precipitation, Inches, June, 1919.

Chart V. Total Precipitation, Inches, June, 1919.

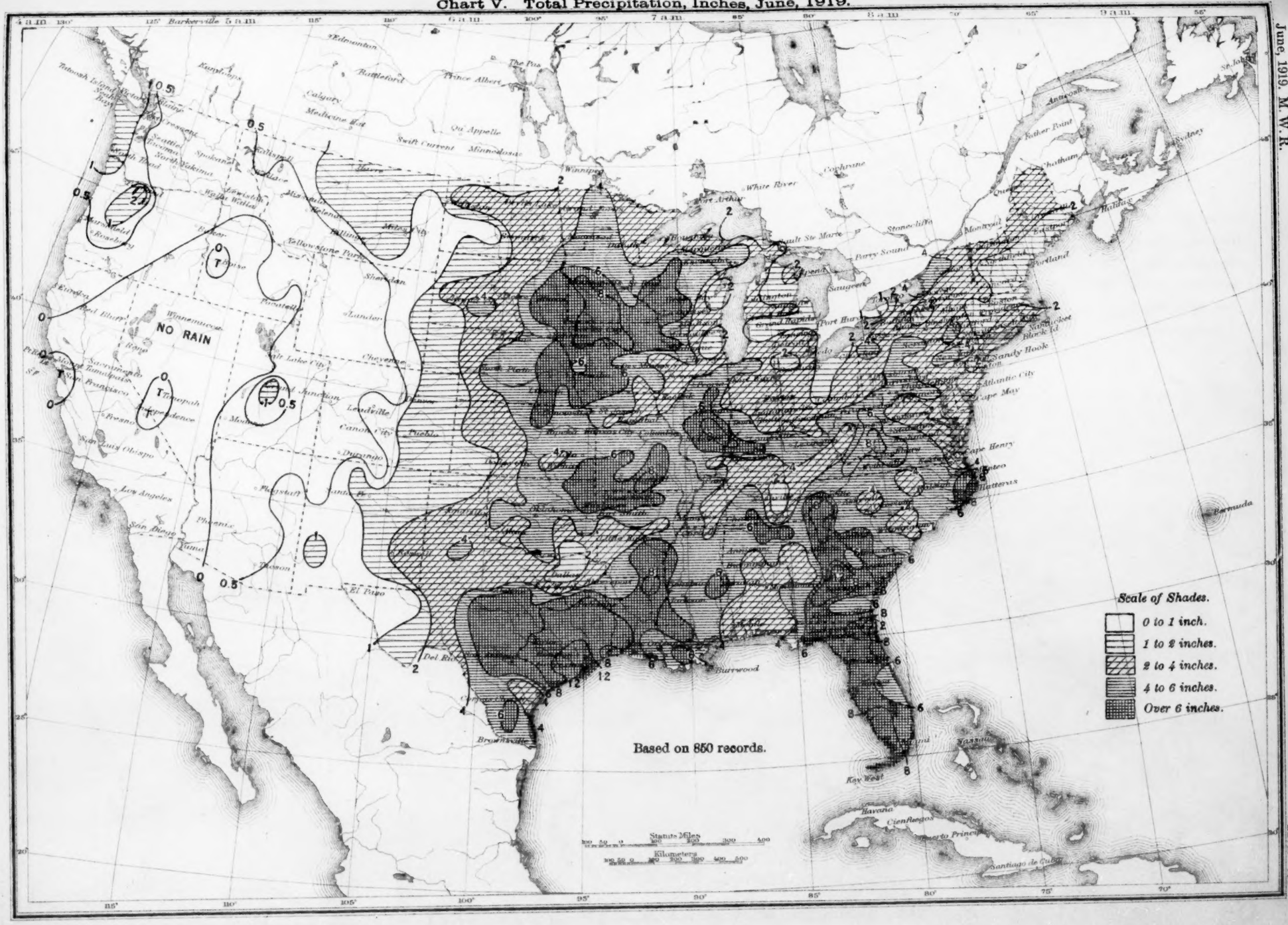


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, June, 1919.

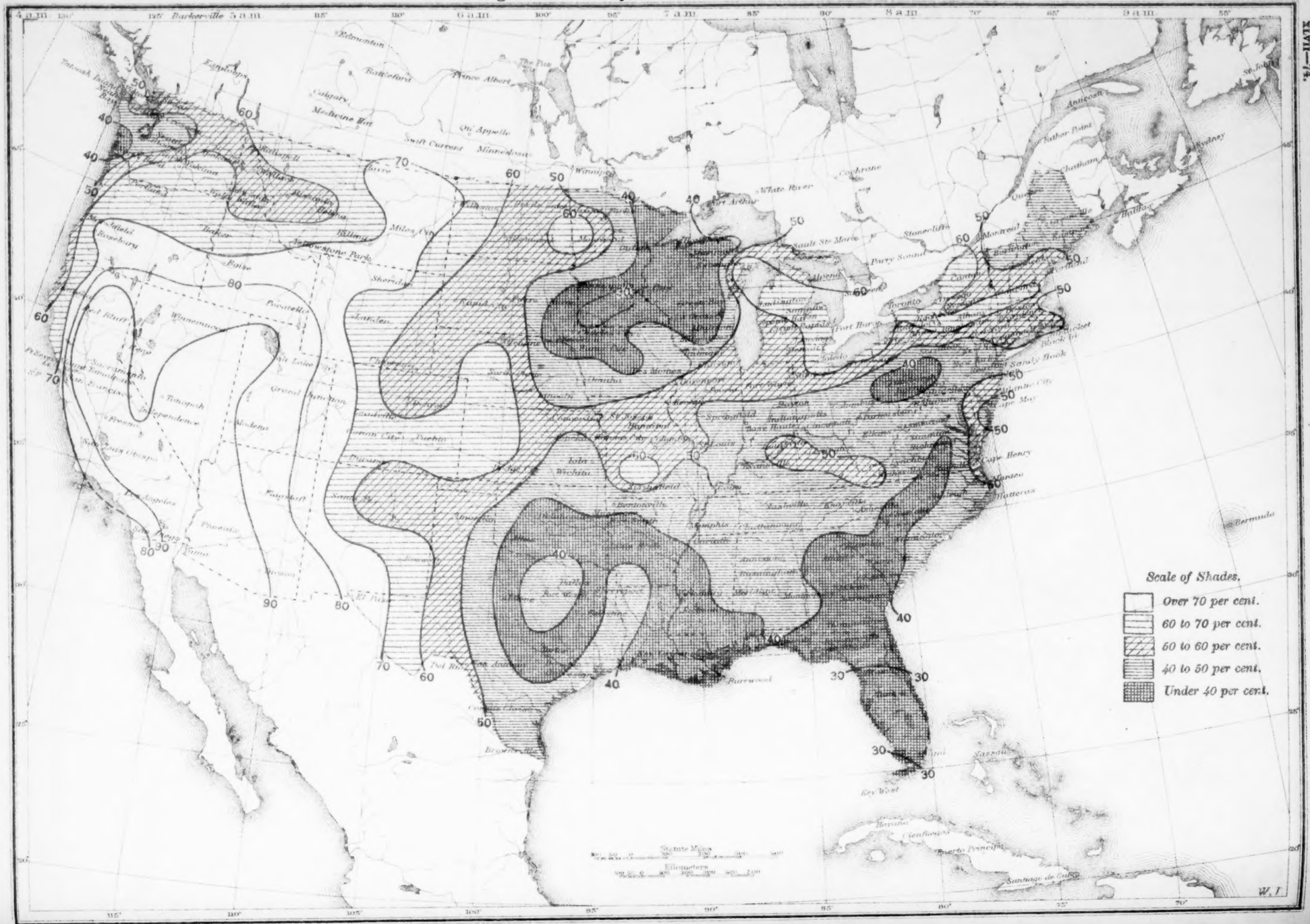


Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, June, 1919.

Chart VII. Isobars and Isotherms at Sealevel; Prevailing Winds, June, 1919.

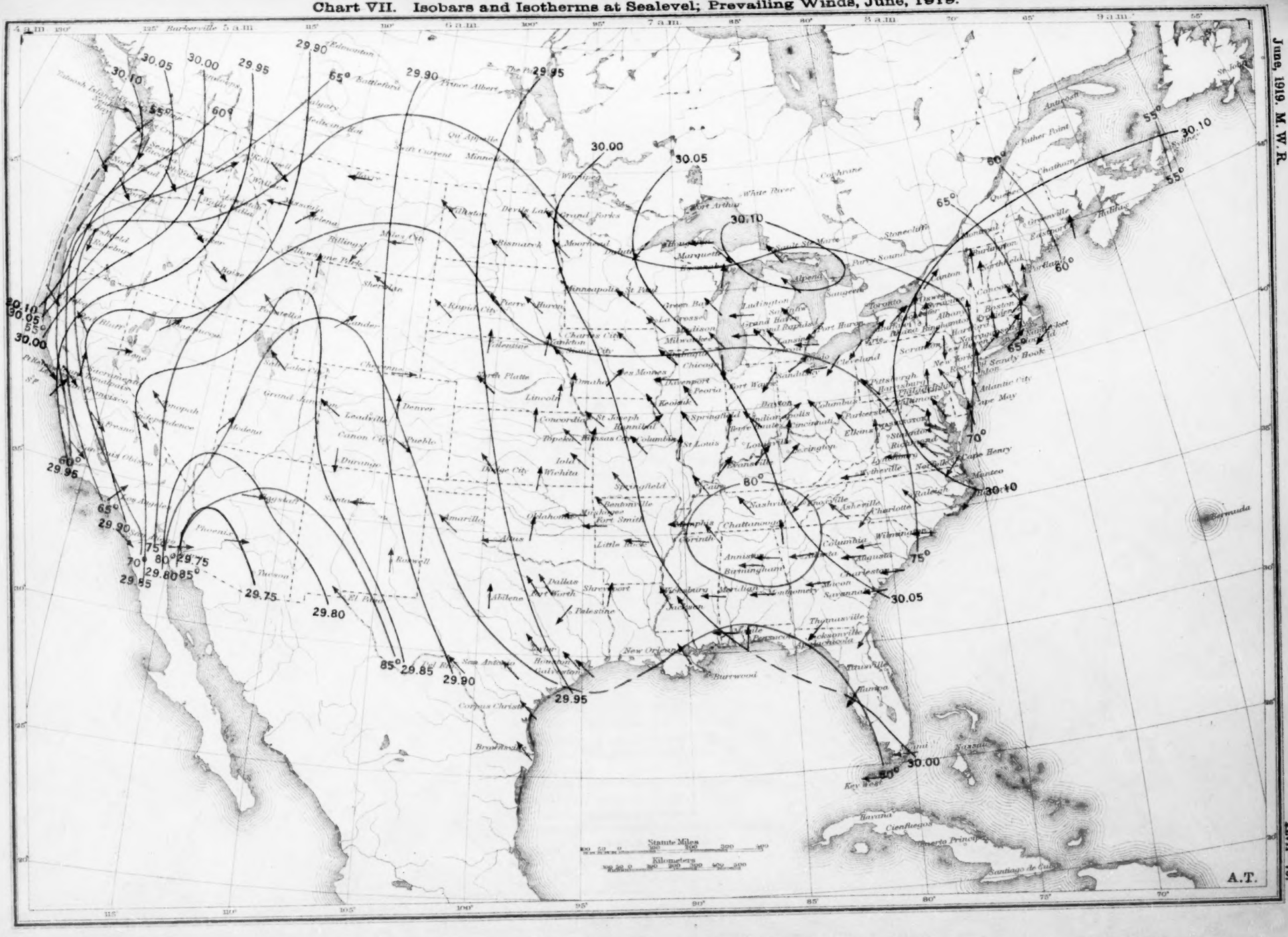


Chart IX. Weather Map of North Atlantic Ocean, June 1, 1919.

(Plotted by F. A. Young.)

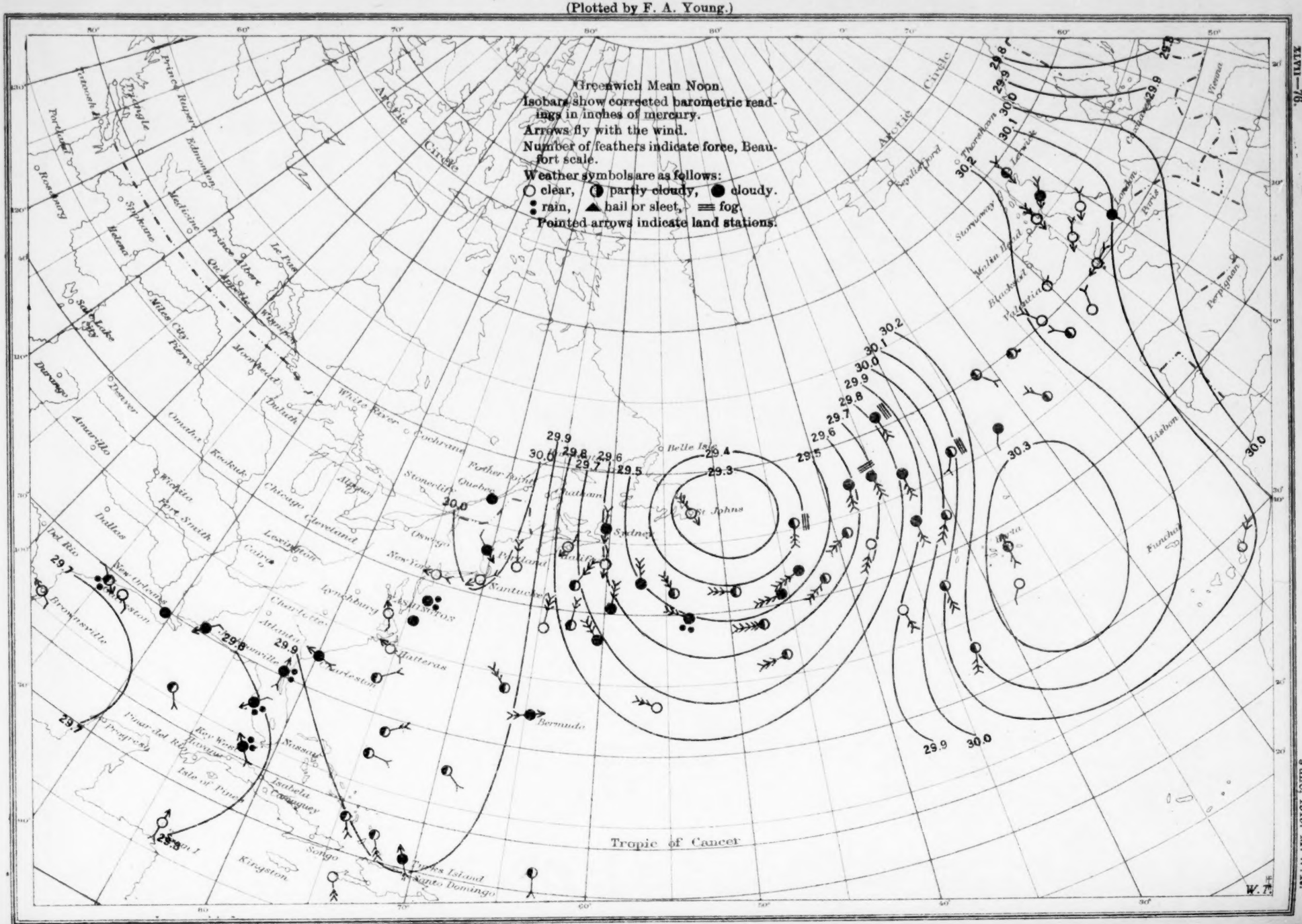

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy.
rain, hail or sleet, fog.
Pointed arrows indicate land stations.
Tropic of Cancer
W. T.

Chart X. Weather Map of North Atlantic Ocean, June 14, 1919.

(Plotted by F. A. Young.)

Chart X. Weather Map of North Atlantic Ocean, June 14, 1919.

(Plotted by F. A. Young.)

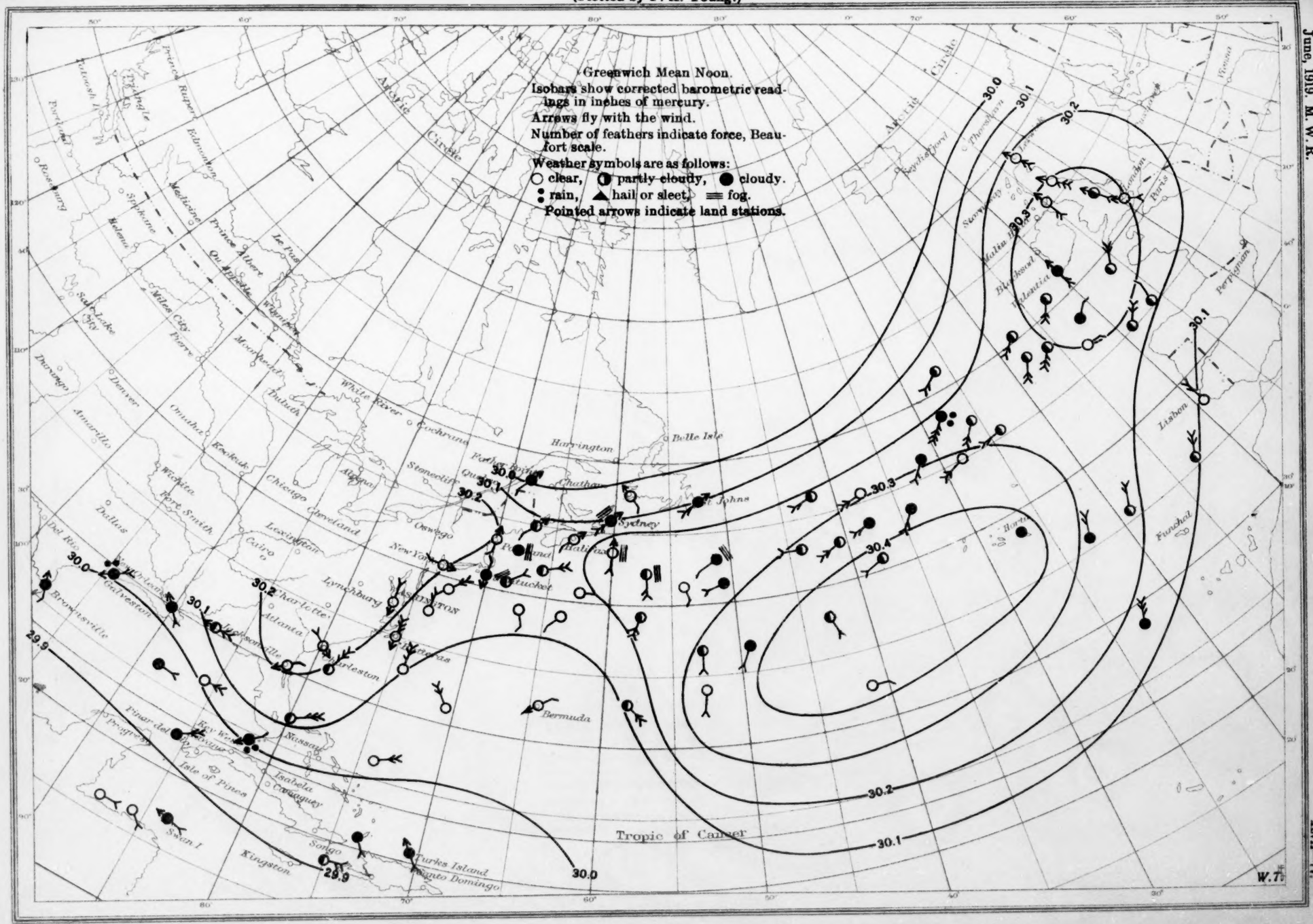
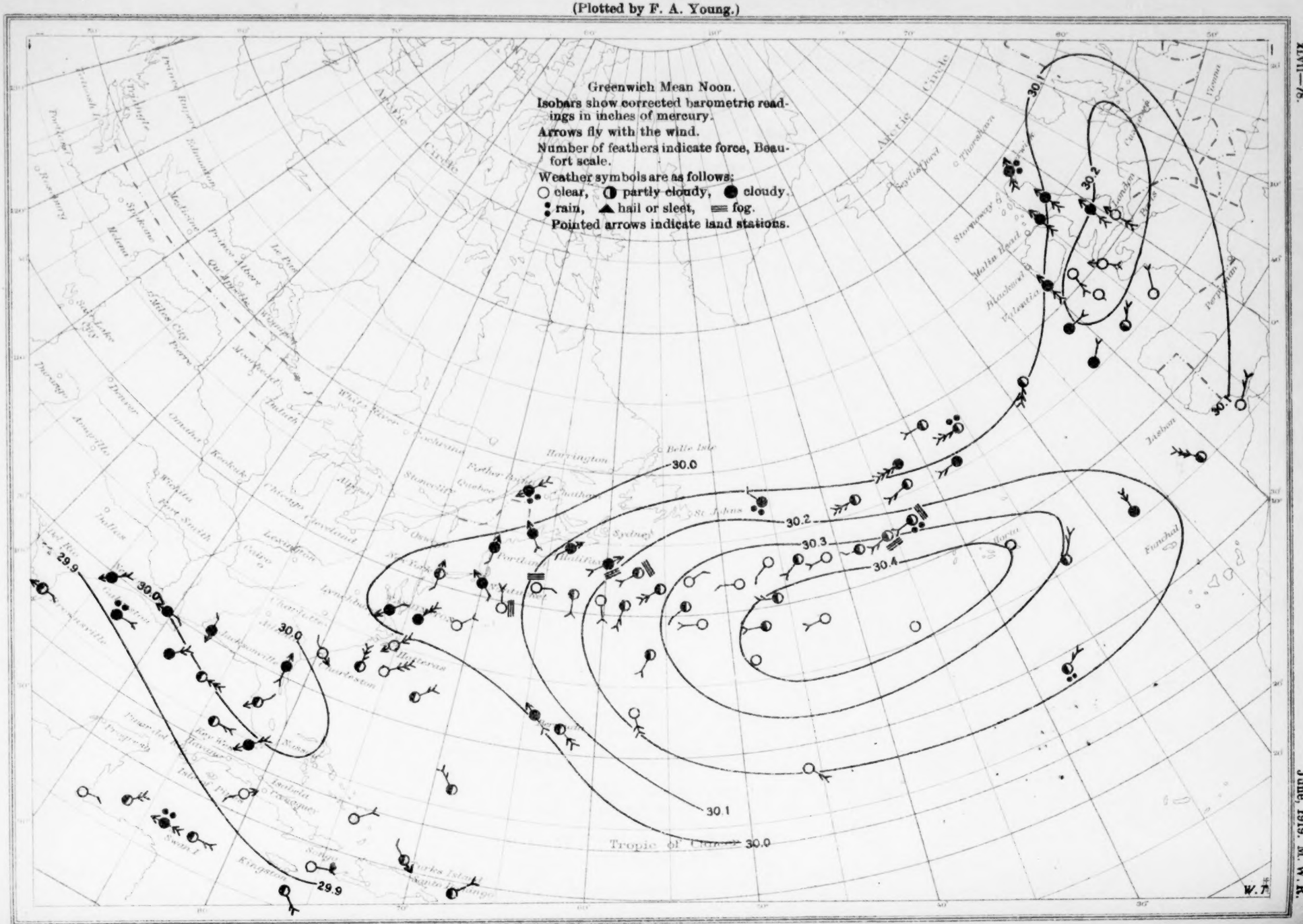


Chart XI. Weather Map of North Atlantic Ocean, June 15, 1919.

(Plotted by F. A. Young.)